Revista Mexicana de Astronomía y Astrofísica, **42**, 15–18 (2006)

CENTIMETER EMISSION IN THE UY AUR SYSTEM

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Received 2005 August 3; accepted 2005 October 7

RESUMEN

Reportamos observaciones de continuo a 3.6 cm tomadas con el Very Large Array (VLA) del joven sistema binario UY Aur. La binaria está compuesta por una estrella T Tauri, UY Aur A, y una llamada "Compañera Infrarroja" (IRC), UY Aur B separadas por $0\rlap{.}''89$. UY Aur es un sistema interesante porque muestra características observacionales cuyo origen no se entiende del todo. Una de estas características es el índice espectral inusualmente bajo que se encuentra en la región del milimétrico. En nuestro estudio con el VLA, hemos detectado radiación continua centimétrica que coincide con las posiciones medidas a 1.3 y 2.7 mm y es consistente con la posición óptica de UY Aur. Concluimos que la emisión a 3.6 cm está asociada con el sistema binario. Más aún, sugerimos que la emisión centimétrica podría estar relacionada con un flujo bipolar previamente reportado.

ABSTRACT

We report 3.6 cm continuum observations taken with the Very Large Array (VLA) of the young binary system UY Aur. The binary consists of a T Tauri star, UY Aur A, and a so-called "infrared companion" (IRC), UY Aur B, separated by $0\rlap{.}''89$. UY Aur is an interesting system because it shows observational features whose origin is not well understood. One of them is the unusual low spectral index found in the millimeter region. In our VLA study, we have detected centimeter continuum radiation that coincides with the reported positions at 1.3 and 2.7 mm and is consistent with the optical position of UY Aur. We conclude that the 3.6 cm emission is associated with the binary system. Furthermore, we suggest that the centimeter emission might be related to a previously reported bipolar outflow.

Key Words: **STARS: BINARIES — STARS: INDIVIDUAL (UY AUR) — STARS: WINDS, OUTFLOWS**

1. INTRODUCTION

The IRC system UY Aur was first reported as a visual double star by Joy & van Biesbroeck (1944). Later, based on an infrared speckle study Ghez, Neugebauer, & Matthews (1993) and Leinert et al. (1993) confirmed that UY Aur is a binary system. Recently, Hartigan & Kenyon (2003) reported the main properties of a sample of subarcsecond binaries in the Taurus-Auriga cloud based on *HST* spectra. They report UY Aur as a binary system composed of two classical T Tauri stars of spectral types M0 and M2.5 for the primary (UY Aur A) and the secondary (UY Aur B) respectively, separated by $0\rlap{.}''89$ ($\sim$ 125 AU at 140 pc).

The system has been studied in detail in the infrared at J, H, and K' by Close et al. (1998). Using infrared adaptive optics, Close et al. detected a circumbinary disk of $\sim$ 500 AU radius. In order to reproduce the spectral energy distribution of UY Aur A and B, they include in their models small inner disks around each star. The derived radii of the circumstellar disks are about 10 and 5 AU for components A and B, respectively. The Close et al. images also suggest that both inner disks are being fed by the outer circumbinary disk through thin streamers of material. In the millimeter region, both line emission (^{13}CO) as well as continuum at 2.7 and 1.3 mm were reported by Duvert et al. (1998). They have imaged the emission from the circumbinary disk in the ^{13}CO $J = 1 \rightarrow 0$ and $J = 2 \rightarrow 1$ transitions. Their spectral line observations agree well with the infrared adaptive optics circumbinary disk reported by Close et al. not only in position but in extent. Regarding the suggested small circumstellar disks,

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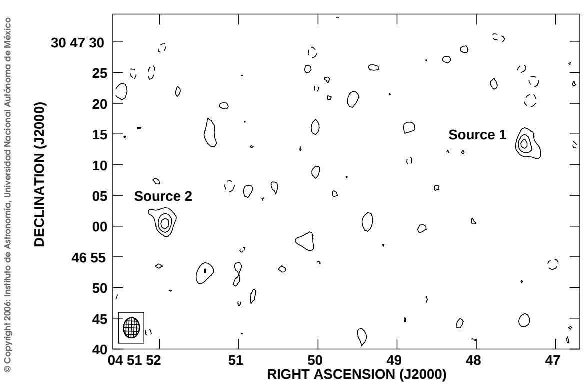

Fig. 1. CLEANed natural weight map at 3.6 cm. The map shows the two sources detected in the UY Aur region. The peak of source 1 is located very close to the UY Aur position and is suggested to be associated to the binary system. Contours are −2,2,4,6 times 16μJy beam^{-1}

TABLE 1

SOURCE PARAMETERS

Source	$\alpha(2000)$ h m s	$\delta(2000)$ ° ′ ″	$S_{3.6\ \mathrm{cm}}$ [mJy]
1	04 51 47.37	30 47 13.3	0.12±0.03
2	04 51 51.93	30 47 00.4	0.11±0.03

Note. Absolute position errors are $\sim 0\farcs2$.

Duvert et al. proposed that the 2.7 and 1.3 mm continuum emission can be attributed to partially resolved circumstellar disks around each star, with some possible contribution of free-free radiation.

In this work we report the first detection of centimetric emission at the position of UY Aur. We conclude that our 3.6 cm continuum detection is associated with the UY Aur system and we discuss a possible origin of it.

2. OBSERVATIONS

Our 3.6 cm observations were made with the Very Large Array (VLA) of the NRAO[3] on 2002 October 9th. The array was in the C configuration giving an angular resolution of $\sim 2\farcs3$ and a total on-source integration time of $\sim$ 51 minutes was obtained. The amplitude and phase calibrators were 0137+331 and 0443+346, respectively. The bootstrapped flux density for 0443+346 was 0.615±0.001 Jy.

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

The data reduction was performed using the Astronomical Image Processing System (AIPS) software of the NRAO. We have followed standard VLA procedures for editing, calibrating and imaging. Figure 1 shows a natural weight CLEANed map of the UY Aur region. In this map two radio sources were detected at a 6σ level. We will refer to these sources as Sources 1 and 2. The peak of Source 1 is located very close to the UY Aur position. Flux densities and source positions were obtained using the AIPS IMFIT procedure. The apparent elongation of Source 1 is not real but it is due to beam deconvolution. Actually, the position angle of both Source 1 and the beam is the same: P.A. = 177°. Besides, small structures present in Source 1 (Figure 2) are not reliable since they are just at a 2σ level above rms noise. Thus, since neither Source 1 nor Source 2 are spatially resolved, we have only determined integrated flux densities and source positions (see Table 1 from a 2D-Gaussian fit to each source.

3. DISCUSSION

Both continuum and line emission are associated with the UY Aur system. Based on their continuum emission at 1.3 and 2.7 mm, Duvert et al. (1998) found an unusual spectral index of 1.6±0.2, which is lower than the one expected for thermal dust emission, $\sim$ 2.5 (Dutrey et al. 1996). Duvert et al. suggest that this low spectral index is the result of a combination of two independent sources: one emitting free-free radiation (showing a flat spectrum) and a second source showing normal dust emission (with a steep positive index). They conclude that the free-free source should be located nearly coincident with or slightly north-east of the primary and propose centimetric observations to confirm this hypothesis.

In this work, we have observed the UY Aur system as part of a radio survey of IRCs. We detected two 3.6 cm continuum sources, Sources 1 and 2 (see Fig. 1), at a 6σ level in the UY Aur region. On one hand, Source 2 does not have a known counterpart at any other wavelength. The *a priori* probability of finding a 3.6 cm source with a flux density of ≥ 0.11 mJy in a region of $2'$ by $2'$ is $\sim$ 0.16 (Windhorst et al. 1993). It is then quite likely that Source 2 is just a background source. On the other hand, Source 1 is located very close to the reported position of UY Aur (Herbig & Bell 1988, hereafter HBC). Then, we propose that our centimeter source is related to the binary system.

In order to confirm that our detected emission is associated with it, we have precessed and corrected

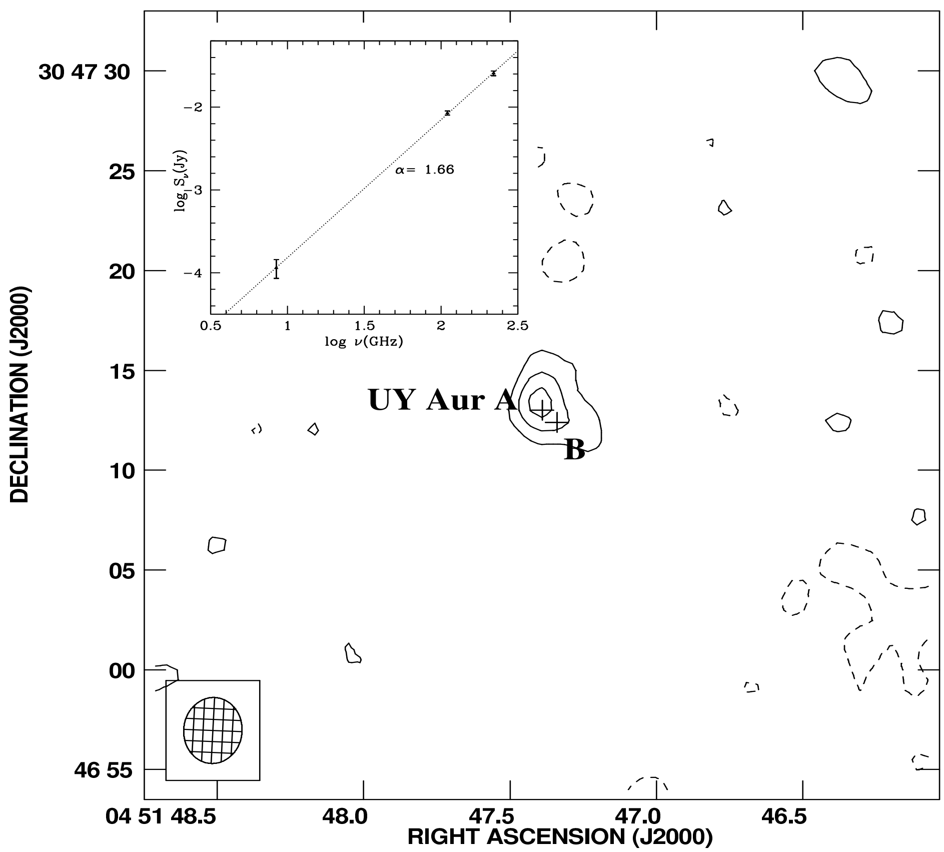

Fig. 2. This map shows an enlarged image of Fig. 1 around UY Aur. Crosses indicate the location of the UY Aur components corrected for precession and proper motion. The inset shows the least squares fit of the spectral index of the cm and mm emission. Contours as in Figure 1.

for proper motion the position of UY Aur according to Jones & Herbig (1979). The resulting position for UY Aur coincides with that of our Source 1 to within $0\rlap{.}''34$, which according to Duvert et al. (1998) is less than the 1–2σ uncertainty in the optical position and proper motion.

Since the main component of the binary (UY Aur A) is the brightest star in the system at optical and infrared wavelengths, we have assumed that the coordinates given in the HBC catalog belong to UY Aur A. Once the position of UY Aur A is fixed, we have derived the second component position relative to it (see Fig. 2) by taking a binary separation of $0\rlap{.}''894$ and a position angle of 228.8° (Brandeker, Jayawardhana, & Najita 2003). On the one hand, our centimeter detection coincides with the position of UY Aur to within $0\rlap{.}''34$ and, on the other hand, it is consistent with the peak positions of the 1.3 and 2.7 mm emission reported by Duvert et al. to within $0\rlap{.}''2$. Besides, although the flux of our detection is low, it is consistent with the lowest centimetric emission of 0.1 mJy present in almost all outflow sources (Reipurth et al. 2004). Therefore, we conclude that our detected 3.6 cm emission is associated with the UY Aur binary system.

Regarding the spectral index, we have obtained a least squares fit to the millimeter and centimeter fluxes. The resulting spectral index, $\alpha = 1.66$, is consistent with that reported by Duvert et al. They have suggested that this low value may be a combination of normal dust emission and free-free radiation from a stellar wind or a jet. However, since both emissions follow a power law distribution (~ 2 for dust radiation and 0.6 for a stellar wind), it is not possible to sum them and still obtain a single power law distribution over such a long range of wavelength without a significant bend. Thus, a satisfactory fit to the observations as the result of combining two such distributions could not be obtained. Although the 3.6 cm flux may originate in free-free radiation, its low value clearly demonstrates that free-free emission is not contaminating the mm flux and does not explain the mm index. Then, the fact that the same low index is maintained over a large wavelength range might be fortuitous or might be entirely due to thermal dust emission.

Duvert et al. (1998) proposed that the millimeter emission originates in the circumstellar region, actually in the small circumstellar disks, one around each component of the binary. The low spectral index in this region could be explained by circumstellar flat-disk models of D'Alessio, Calvet, & Hartmann (2001) where they show that disks whose spectral index is smaller than 2 are flat and the observed millimeter emission is due to optically thick and cold material. But what about the origin of our centimeter emission? The centimeter emission might originate in a stellar wind or an ionized jet as Duvert et al. (1998) have suggested. This last possibility might be supported by a kinematic study of Hirth, Mundt, & Solf (1997). They deduce the existence of a bipolar, high velocity flow at a P.A. = 40° (P.A. = 220°) associated with UY Aur. Then, our 3.6 cm emission may be related to this outflow. If the 3.6 cm flux is due to free-free emission, from our single wavelength observation it is not possible to distinguish between emission from a jet and a stellar wind. However, since our radio detection falls along the same power law distribution obtained from the millimeter observations (see inset of Fig. 2), we cannot discard the possibility that it might be the long wavelength continuation of the thermal dust emission. Further observations at higher resolution and additional wavelengths are needed.

4. SUMMARY

We report for the first time VLA continuum emission at 3.6 cm associated with the binary IRC system UY Aur. Surprisingly, our centimetric emission follows closely the low spectral index obtained in the millimeter region. This low index might be explained by a flat, optically thick and cold circumstellar disk, in this case one or both of the two small circumstellar disks. On the other hand, if the 3.6 cm emission is due to free-free radiation, it may be related to the bipolar outflow reported by Hirth et al. (1997).

However, from our single observation it is not possible to distinguish between free-free emission from a jet or a stellar wind. Radio centimeter observations at other wavelengths and/or with higher resolution are required to further clarify the origin of the radio continuum emission.

We thank L. F. Rodríguez and P. D'Alessio for their valuable comments on this work. We acknowledge financial support from DGAPA-PAPIIT and CONACyT-Ciencias Básicas. F.P.W. also was supported by the NSF International Researchers Fellowship Program.

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