High resolution near-infrared interferometric imaging of the ultracompact H II region K3-50 A

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Abstract

We present K'-band bispectrum speckle interferometry of the ultracompact H II region K3-50A. Our image resolves the central $1'' \times 1''$ region into at least 7 point-like objects. We find K'-band counterparts for all but one of the N-band sources discovered by Okamoto et al. (2003), and there are additional K'-band sources which were unresolved in the N-band images. Our reconstructed image also reveals the fine-structure of the cone-shaped nebulosity extending to the south. The brightest K'-band source is located exactly at the tip of the cone-shaped nebulosity. The nebula shows several arcs and the orientation of its main axis agrees very well with the direction of the CO outflow from K3-50A. This nebulosity therefore very likely represents the clumpy inner surface of a partially evacuated cavity excavated by the strong outflows.

Observations and data analysis

The speckle interferograms of K3-50 A were recorded on 24 September 2002 with the SAO 6 m telescope in Russia using a K'-band filter. The exposure time per frame was 300 ms. Our data set consists of 980 speckle interferograms of K3-50 A and of the unresolved reference star. The seeing was $\sim 1.1''$ (FWHM). An image with a resolution of 106 mas (Fig. 1) was reconstructed using the bispectrum speckle interferometry method (Weigelt 1977; Lohman et al. 1983).

Results

Our speckle image shows a bright, point-like source at the northern tip of a cone-like nebula extending towards the south, in which a number of fainter, point-like sources (in the following denoted with the numbers 1 to 10) are embedded.

Comparing our image with the $0.4''$ resolution seeing-limited K-band image presented by Okamoto et al. (2003; their Fig. 3 and 4) allows a reliable cross-identification of the sources. Our brightest source 1 corresponds to the brightness peak in the seeing-limited K-band image of Okamoto et al. (2003), and our sources 8 and 10 can be reliably identified with point-like sources in their image. The rest of our sources, i.e. numbers 2 to 7 and number 9, are not resolved in the K-band images of Okamoto et al. (2003).

Since Okamoto et al. (2003) suggested that the brightest K-band source corresponds to the $10\,\mu$m source OKYM 3, we assume here that our source 1 is positionally coincident with OKYM 3. This cross-identification also allows us to search for counterparts of the N-band sources in our K-band speckle image (see Table 1).

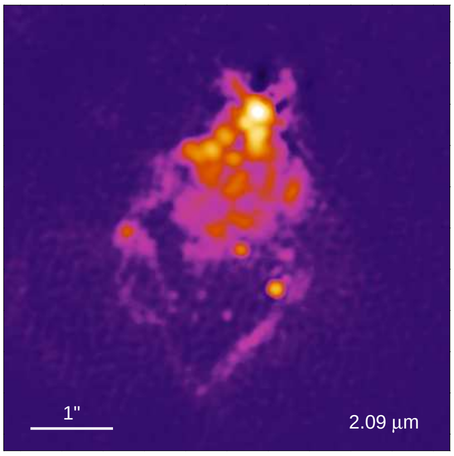

Figure 1: Pseudocolor representation of our K'-band image of K3-50 A, reconstructed with the bispectrum speckle interferometry method. This image has a resolution of 106 mas, the field of view is $\sim 5.4'' \times 5.4''$. North is up and east is to the left.

Only for the $10\,\mu$m source STHO 1 we can see no counterpart in our K-band image. Our speckle image directly confirms the presence of multiple sources in the core of K3-50 A, and confirms the indication from the N-band data that OKYM 2 and OKYM 3 are separate sources.

We can use the observed magnitude differences to check the suggested spectral types of the main sources in the K3-50 A core (Okamoto et al. 2003): if we assume that the relative K'-band magnitudes of the sources are roughly representative of their relative luminosities, we find that the 4.5 times smaller flux of the second brightest source is consistent with a spectral type $\sim$ B0 if the brightest source is of spectral type $\sim$ O8. Therefore, the spectral type estimates of the ionizing sources in K3-50 A derived by Okamoto et al. (2003) are supported by our data.

It is also interesting to compare the K'-band and N-band fluxes of the sources. Inspection of the N-band spectra (Okamoto et al. 2003) of OKYM 3 (our source 1) and OKYM 4 (our source 10) shows that these two sources have quite similar fluxes at $\sim 10\,\mu$m. In the K'-band, however, OKYM 4 is more than 4 magnitudes fainter than OKYM 3.

If the intrinsic properties of both objects were identical, this difference in $K' - N$ color would indicate that OKYM 4 suffers from about 140 mag more optical extinction than OKYM 3. Alternatively, OKYM 4 may also be surrounded by a much larger amount of warm ($T \sim 500$ K) circumstellar material than OKYM 3, causing a strong mid-infrared excess.

This might suggest that source 10 is surrounded by a much larger amount of warm circumstellar material than source 1.

source number	Δ RA [mas]	Δ Dec [mas]	Δ K' [mag]	Ident. with Okamoto et al. (2003) K-band	N-band
1	0	0	0	yes	OKYM 3
2	135	-108	1.74	saturated/unresolved	
3	13	-256	1.65	saturated/unresolved	OKYM 2
4	405	-283	3.13	unresolved	
5	567	-445	2.83	unresolved	OKYM 1
6	742	-513	3.36	unresolved	
7	297	-567	3.84	unresolved	
8	-216	-2146	2.61	yes	
9	202	-1674	3.65	?	
10	1593	-1431	4.08	yes	OKYM 4

Table 1: Relative positions and photometry for the point like sources in our K'-band bispectrum speckle image. The J2000 coordinates of source 1 determined from the 2MASS K-band image are R.A. 20:01:45.7, Dec +33:32:44

The diffuse emission

The main axis of the diffuse cone-shaped nebulosity surrounding the point-like sources is P.A.$\sim 175°$. This agrees quite well with the position angle of P.A.$=160°$ that was found for the high-velocity bipolar radio outflow by DePree et al. (1994). The full opening angle is $90°$. Other very interesting features are the straight edges of the diffuse nebulosity and the X-like structure around the brightest source. The direction of the short northern extensions corresponds well with the directions of the edges in the southern direction. This structure therefore seems to represent a well defined cone with source 1 at its center.

These results suggest the following interpretation of the nebulosity: what we see is the clumpy inner surface of a partially evacuated cavity in the circumstellar envelope around the central source, which has probably been excavated by the strong outflow.

The fact that the southern part of the cavity is much brighter than the norther part, suggests that the southern outflow structure is tilted towards the line-of-sight and that we look “into” the southern cavity.

The diffuse emission has a very clumpy structure with several prominent knots and some rather sharp and straight features. We note that the general morphology of the diffuse structures in our K-band speckle image is very similar to that seen in the N-band image of Okamoto et al. (2003).

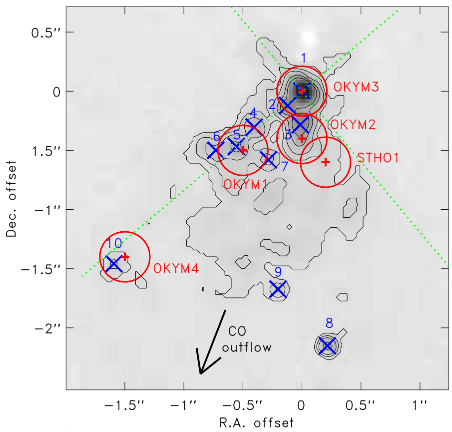

Figure 2: Greyscale representation of the central part of our K-band speckle image with annotation of the objects discussed in the text. The red crosses mark the $10\,\mu$m sources detected by Okamoto et al. (2003), the red circles give the positional uncertainty. The blue crosses mark the point-like sources in our K-band speckle image for which we performed aperture photometry. The direction of the CO outflow is indicated by the arrow.

One of the most peculiar features is the V-shaped structure at the southern end. The western part of the V-shaped structure corresponds to the northern part of “arc 1” defined by Okamoto et al. (2003). In our speckle image this part of the arc appears very sharp and remarkably straight.

It is also interesting to note that all the point-like K-band sources in our image are located within (or very close to the edges of) the southern cavity. As it seems quite unlikely that all members of a stellar cluster assemble in a cone-like volume and not in a roughly spherical distribution around the central source, this may imply that we can detect only those objects that are located in the cavity, because the extinction along the line-of-sight through the cavity is much lower than through other parts of the cloud.

Summary and conclusions

Our high-resolution imaging resolves the central K'-band emission of K3-50 A into 10 point-like sources. The brightest K'-band source dominates the near-infrared emission and since it is centered on the bipolar cavity structure, it also seems to be the dominant driving source of the molecular outflow. However, the magnitudes of the other point-like sources indicate that some of them are also rather massive (probably early B-type) stars. This suggests that K3-50 A is not dominated by a single massive star, but by a small cluster of massive to intermediate-mass stars. Our results demonstrate the importance of high spatial resolution observations for revealing the true nature of massive YSOs.

References

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