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## VLTI / MIDI Observations of the Massive Protostellar Candidate NGC 3603 IRS 9A

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**Abstract.** We used MIDI, the mid-infrared interferometric instrument of the VLTI, to observe the massive protostellar candidate IRS 9A, located at a distance of about 7 kpc at the periphery of the NGC 3603 star cluster. Our ongoing analysis shows that MIDI almost fully resolves the object on all observed baselines, yet below  $9\ \mu\text{m}$  we detect a steep rise of the visibility. This feature is modelled as a combination of a compact hot component and a resolved warm envelope which lowers the correlated flux at longer wavelengths. The extended envelope can already be seen in both MIDI's acquisition images and in complementary data from aperture masking observations at the Gemini South telescope. Its shape is asymmetric, which could indicate a circumstellar disk inclined against the line of sight. The compact component is possibly related to the inner edge of this (accretion) disk. The uncorrelated mid-infrared spectrum appears featureless and could be caused by optically thick emission without a significant contribution from the disk atmosphere.

### 1. Introduction

The giant HII region NGC 3603 is powered by one of the densest clusters of high mass stars known in our galaxy. Due to its vicinity to this cluster, IRS 9A has been liberated from most of the gas and dust of its natal molecular cloud by the strong stellar winds and ionising radiation arising from the nearby O-type main-sequence stars. This offers the unique possibility to observe a high mass star at infrared wavelengths during its relatively early evolutionary phase.

### 2. Observations and data reduction

IRS 9A was observed with MIDI (Leinert et al. 2003) during three nights in 2005. The first two observations were carried out on the 26th and the 27th

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Telescopes	Date	Time	B <sub>p</sub> [m]	P.A. [°]
UT2–UT3	2005-02-27	08:35:10	31.8	79.8
”	2005-02-28	06:48:35	38.0	60.8
”	”	07:43:50	34.9	70.8
”	”	08:33:25	31.7	80.2
”	”	09:21:12	28.1	90.1
UT3–UT4	2005-03-03	07:10:49	62.5	131.9
”	”	08:54:33	62.0	155.5

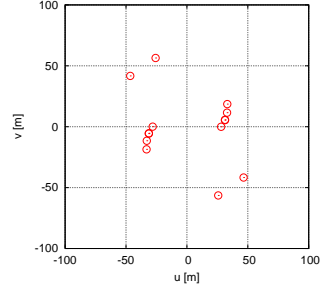


Figure 1. Log of observations and plot of the  $u, v$  - coverage of IRS 9A

of February, using the VLT telescopes UT2 and UT3. The third observation, performed on the 2nd of March, was executed with telescopes UT3 and UT4. A short observing log, containing the length of the projected baselines and the position angles, and a plot of the corresponding  $u, v$  - coverage are shown in Figure 1.

The star HD107446 has been chosen as a calibrator and was observed repeatedly during the three aforementioned nights. The rather complex observing procedure is described in detail in Przygodda et al. (2003) and Leinert et al. (2004), and will not be presented here. Data reduction was performed with the MIA+EWS package, which is provided by the MIDI consortium.

## 2.1. Images

Before any interferometric data are taken, MIDI records acquisition images to center the target in the FOV. Since the scaling of the Fried parameter  $r_0$  is favourable for observations in the infrared ( $r_0 \propto \lambda^{6/5}$ ) and an adaptive optics system is used, these images are diffraction limited and have a resolution of about  $0''.3$ . They show that the envelope of IRS 9A is already partly resolved by a single 8 m telescope in the N band, and that the shape of the extended flux is asymmetric. This asymmetry is further supported by aperture masking data from T-ReCS on Gemini South, which was kindly provided by John D. Monnier (priv. comm.). Figure 2 shows one of the acquisition images taken with MIDI and the image from Gemini South, reconstructed with the Maximum Entropy Method. They agree in overall shape and show that the circumstellar emission is indeed quite extended. At the distance of IRS 9A,  $0''.1$  correspond to 700 AU, and the bulk of the emission therefore originates in a region of about 3000 AU in diameter.

## 2.2. Spectrum

The mid-infrared spectrum is obtained by standard chopping techniques and does not show any prominent emission or absorption features (see Figure 3). A small dip and bump at approximately  $9.4 \mu\text{m}$  can be seen in the spectra from the first two nights, but this is most likely an artefact of imperfect calibration, since there is strong absorption due to Ozone in the atmosphere at this wavelength. On top of that, one apparently sees a faint silicate absorption feature ranging from  $9 \mu\text{m}$  to  $11.5 \mu\text{m}$ . Nevertheless the overall spectrum can be reproduced by a single black body of about 250 K.

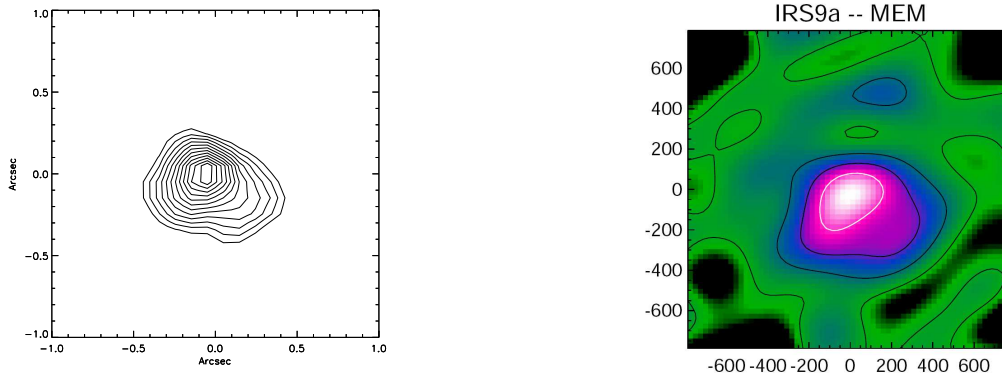


Figure 2. Left: Acquisition image from VLTI + MIDI. Right: MEM image from Gemini South + T-ReCS aperture masking data (J. Monnier, priv. comm.; scale on both axes is in units of mas).

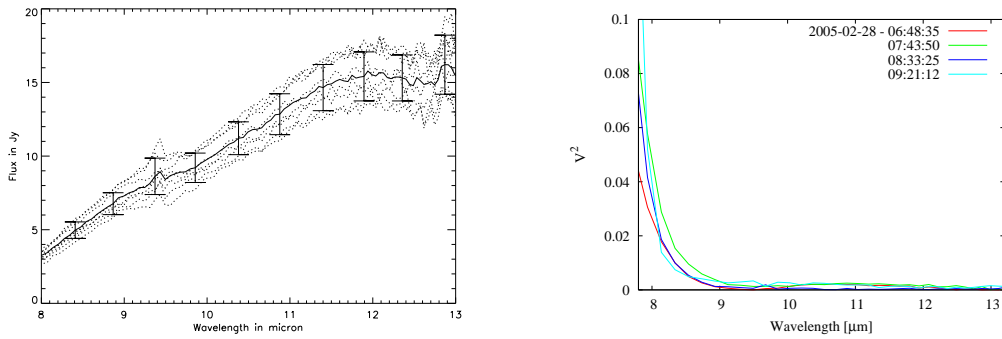


Figure 3. Left: Spectra obtained during the second night. The dashed lines are the individual measurements, the solid line shows the average together with the standard deviation as error bars. Right: Corresponding visibility measurements from the same night.

### 2.3. Visibilities

Given the detection of the extended envelope around IRS 9A we already expected the visibilities to be quite low. Figure 3 shows the calibrated and squared visibilities of the second night. Their value is basically zero above a wavelength of  $9 \mu\text{m}$ , but there is a very steep rise with decreasing wavelength below  $9 \mu\text{m}$ . However, even the largest values are only of the order of 0.1 and lie at the very edge of the atmospheric window. Except for one observation on the 3rd of March, all the measurements are in good agreement and do not show a strong dependency on the position angle, if any.

## 3. Modelling the SED and the visibilities

Apart from the spectrum taken with MIDI we have at hand additional mid-infrared fluxes of IRS 9A (Nürnberg 2003). We use two publicly available radiative transfer codes to model the spectral energy distribution of IRS 9A: The first one is DUSTY (Ivezić, Nenkova, & Elitzur 1999), which solves the

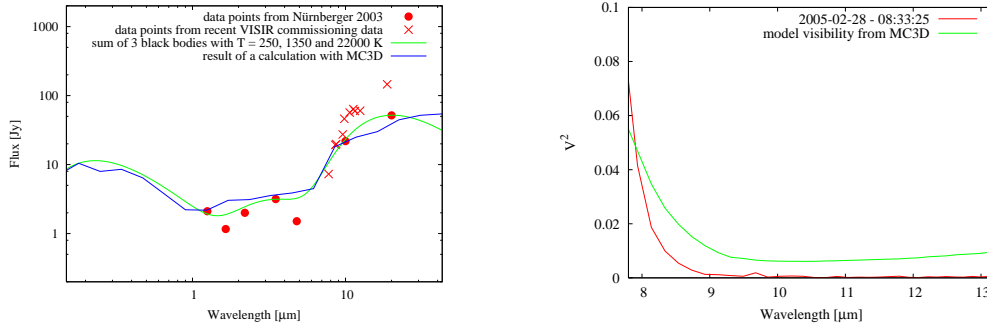


Figure 4. Left: SED model obtained with MC3D in comparison to the sum of three black bodies and our additional near-infrared data. Right: The visibility of this model compared to one of the measurements.

radiation transport for a spherical dust distribution. The second one is MC3D (Wolf, Henning, & Stecklum 1999), which can handle more complex geometries but uses Monte Carlo methods to solve the radiation transport. Both models are able to reproduce the SED quite well.

The radiative transfer codes allow to create maps of the surface brightness for a given wavelength, which can then be used to calculate the wavelength dependent visibilities. The DUSTY model yields visibilities which are not too far from our measurements, but the visibility below  $9\ \mu\text{m}$  rises rather gently, and it also shows a bump between  $9$  and  $10\ \mu\text{m}$ . The visibilities from our MC3D model produce a better fit to the observed data, but the slope below  $9\ \mu\text{m}$  is still not steep enough. Figure 4 shows the results obtained with MC3D.

#### 4. Discussion

Our ongoing analysis of the MIDI data shows IRS 9A to be almost completely resolved on baselines of the order of the order of 30 m. The mid-infrared spectrum is featureless, and most likely caused by emission from a warm envelope. The models are so far unable to account for the steep rise of the visibility towards the short wavelength end, so that the nature of this compact component remains unclear and further refinements of the models are needed.

**Acknowledgments.** We would like to thank J. D. Monnier for kindly providing his IRS 9A data from Gemini South.

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