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

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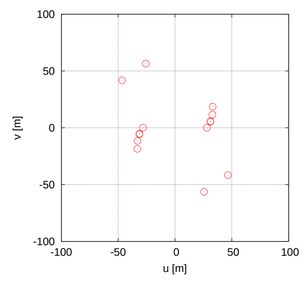
Abstract: We used MIDI, the mid-infrared interferometric instrument of the VLTI, to observe the massive protostellar candidate IRS 9A, located at a distance of about 7 kpc at the periphery of the NGC 3603 star cluster. Due to strong stellar winds and ionising radiation produced by the hot O and B stars in the centre of the cluster, IRS 9A has been liberated from most of the gas and dust of its natal molecular cloud, and is now only embedded in the gravitationally bound material of its circumstellar envelope. This offers the unique possibility to observe a high mass star at infrared wavelengths during its relatively early evolutionary phase. The ongoing analysis of our MIDI data shows that MIDI almost fully resolves the object on all our baselines, yet below 9 μm, towards the short wavelength end of the atmospheric N band, 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 is featureless and could be caused by optically thick emission without a significant contribution from the disk surface. The steep rise of the visibilities with decreasing wavelenghts below 9 μm could be explained by absorption at the blue end of the spectrum, if it is the extended flux which is absorbed.

Observations:

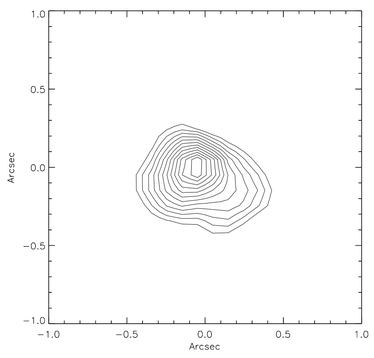
Our target IRS 9A was observed with MIDI during three nights at the beginning of 2005. We used two different baseline settings. A short observing log and a plot of the *u,v* - coverage are shown below. The star HD107446 was chosen as a calibrator; it was observed before and after the data of IRS 9A were taken. The data were reduced with the MIA+EWS package, which is provided by the MIDI consortium.

Telescopes	Date	B_{proj} [m]	P.A. [deg]
UT2 – UT3	2005-02-27 – 08:35:10	31.8	79.8
UT2 – UT3	2005-02-28 – 06:48:35	38.0	60.8
UT2 – UT3	07:43:50	34.9	70.8
UT2 – UT3	08:33:25	31.7	80.2
UT2 – UT3	09:21:12	28.1	90.1
UT3 – UT4	2005-03-03 – 07:10:49	62.5	131.9
UT3 – UT4	08:54:33	62.0	155.5



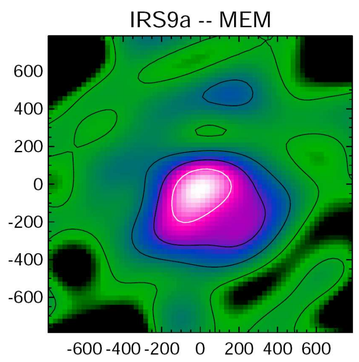
MIDI acquisition images:

Before any interferometric data are taken, MIDI records acqusition 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 the data from Gemini South.



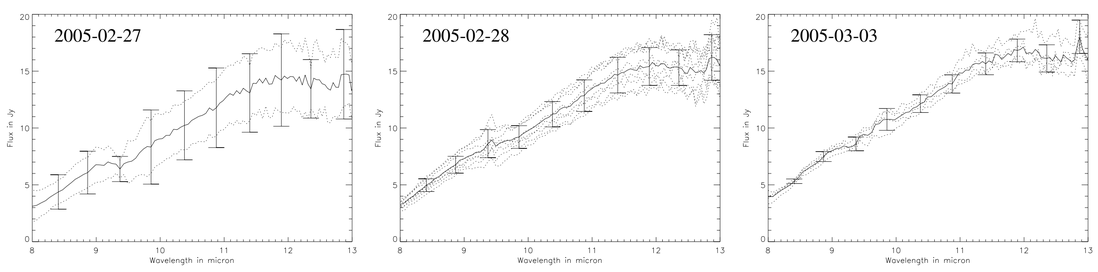
Gemini South data:

Also in 2005, aperture masking observations of IRS 9A were carried out by John Monnier (priv. comm.) at the Gemini South telescope. The data were taken at 11.7 μm with the T-ReCS instrument, which is Gemini's mid-infrared imager and spectrograph. Using the Maximum Entropy Method, J. Monnier constructed an image from the interferometric data which is displayed to the right (scale is in mas). It agrees in overall shape with the MIDI acquisition images, and confirms 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.



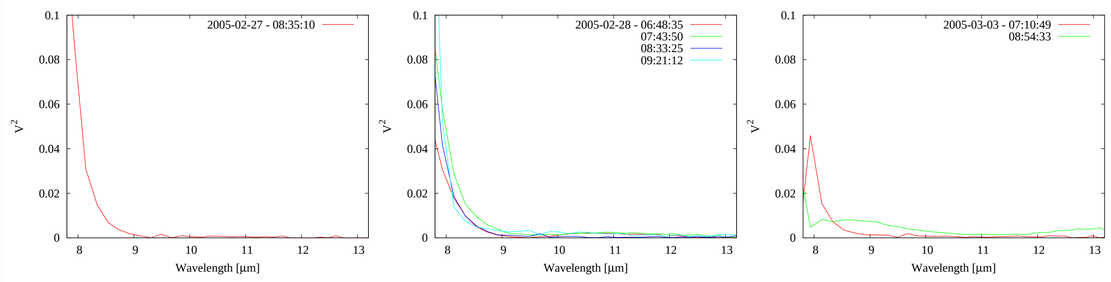
Spectra:

With MIDI the spectrum of the target is obtained by first blocking the light from one telescope and then blocking the light from the other. Therefore the plot of the single observation during the first night shows two dashed lines, and the solid line is their average. The mid-infrared spectrum as seen by MIDI does not show any emission or absorption features. The small dip and bump at approximately 9.7 μm, which can be seen in the two plots on the left, is most likely an artefact of imperfect calibration, since there is strong absorption due to Ozone in the atmosphere at this wavelength. The spectrum can be reproduced by a single black body of about 250 K.



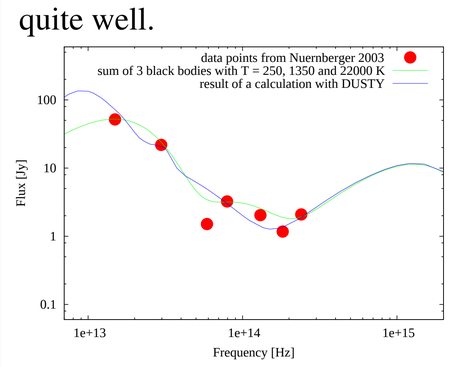
Visibilities:

Given the detection of the extended envelope around IRS 9A we already expected the visibilities to be quite low. The three plots below show the calibrated and squared visibilities of IRS 9A versus wavelength. Their value is basically zero above a wavelength of 9 μm, but there is a very steep rise with decreasing wavelength below 9 μm. 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.



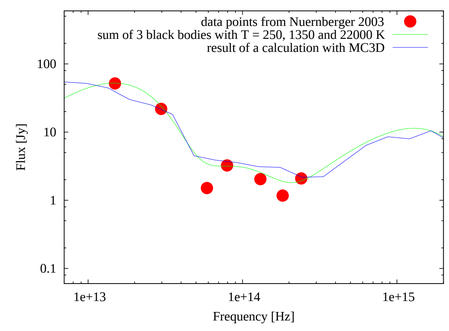
Modeling the SED:

Apart from the spectrum taken with MIDI we have at hand additional mid-infrared fluxes of IRS 9A (Nürnberger, 2003). We use two publicly available radiative transfer codes to model the spectral energy distribution of IRS 9A: The first one is DUSTY (Ivezić et al., 1999), which solves the radiation transport for a spherical dust distribution. The second one is MC3D (Wolf et al., 1999 and Wolf, 2003), which can handle more complex geometries but uses Monte Carlo methods to solve the radiation transport. Both models are able reproduce the SED quite well.



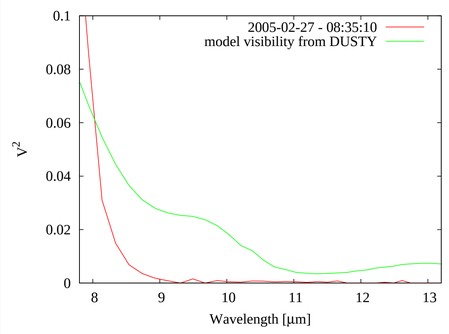
Left: SED model from DUSTY.

Right: SED model from MC3D.



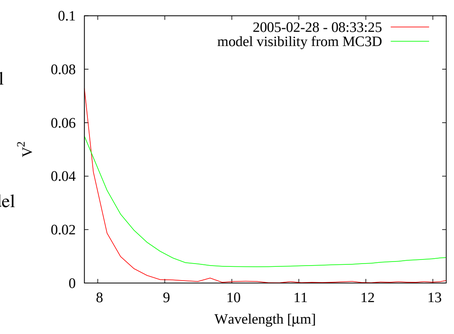
Modeling the visibilities:

Both DUSTY and MC3D are able to produce maps of the surface brightness for a given wavelength, which can then be used to calculate the wavelength dependent visibilities. The above DUSTY model yields visibilities which are not too far from our measurements, but it is unable to reproduce the steep rise below 9 μm. Instead, the visibility rises rather gently, and also shows a bump between 9 and 10 μm. The visibilities from our MC3D model produce a better fit to the observed data, but the slope below 9 μm is still not steep enough and further refinements of the model are needed.



Left: Visibility model from DUSTY.

Right: Visibility model from MC3D.



References:

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Background image: ESO