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Modeling the massive young stellar object NGC 3603 IRS 9A*

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Abstract: We present results from our high angular resolution observations of the brightest high-mass young stellar object in NGC 3603, IRS 9A. Both MIDI at the VLTI and T-ReCS equipped with an aperture mask at Gemini South have resolved the mid-infrared dust emission on scales of 30 mas to 300 mas, corresponding to scales of 200 AU to 2000 AU. A flattened envelope or disk-like dust structure is the only way to explain why MIDI was able to detect a compact warm source in the presence of extended emission fully resolved even on 8 meter baselines. We have therefore described the structure using disks and envelopes based on models by Whitney et al., and can find reasonable agreement with the visibility measurements and the SED as measured by Spitzer.

1 Introduction

1.1 Motivation

Massive young stellar objects are usually deeply embedded in their natal environment which can be penetrated only at wavelengths long-ward of the near IR. In addition, sites of high-mass star formation are generally quite distant, hence require high angular resolution observations with interferometers. The MIDI instrument on the VLTI was therefore a perfect choice for us to study IRS 9A, at 7 kpc, in the star forming region of NGC 3603.

1.2 Environment

The molecular cloud from which IRS 9A was born has been largely eroded away by the radiation of the cluster of hot stars some 2.5 pc (projected on the sky) to the north-west. All obscuring gas and dust is gravitationally bound to the star and thus allows us to study the accretion in more detail. The foreground extinction is adopted to be $A_V = 4.5$ mag (Brandl et al. 1999).

*Based in part on observations collected at the European Southern Observatory and the Gemini South Observatory, Chile

Figure 1: JHK composite image taken with ISAAC at VLT-ANTU by Brandl et al. (1999). IRS 9A is the bright-orange source in the lower left. North is up, East to the left. The height of the image covers 1.9 arcminutes (3.5 pc).

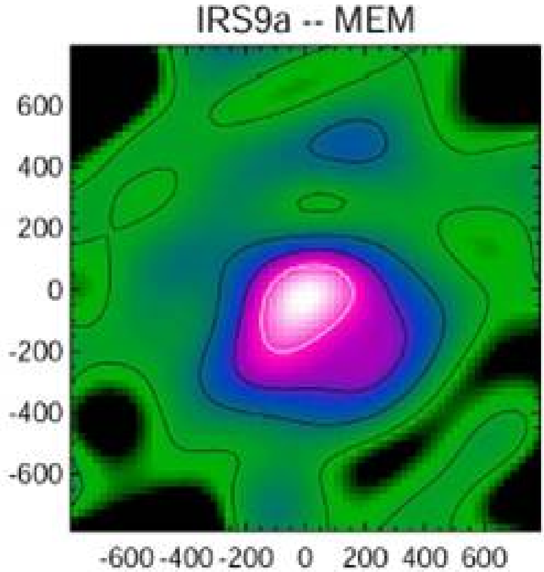

Figure 2: Image reconstructed from sparse-aperture masking observations at 11.7 microns at the Gemini South Telescope using the T-ReCS instrument (Vehoff et al. 2010). The scale is in milli-arcseconds, North is up and East to the left. Countours are at 30%, 15%, and 5% of the peak.

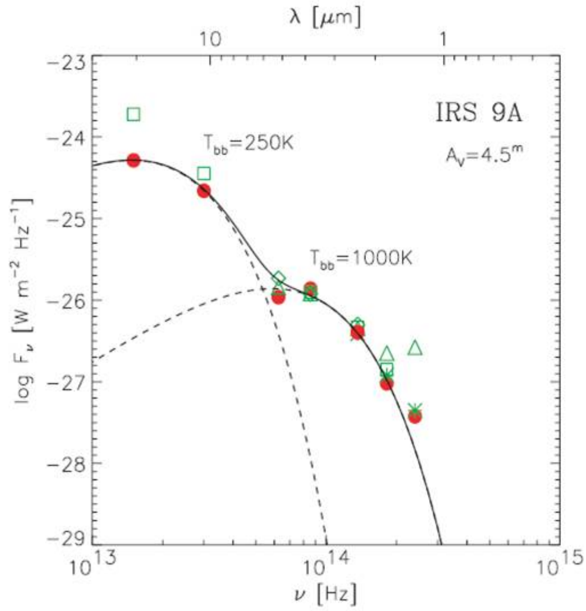

Figure 3: The SED of IRS 9A dereddened for the foreground extinction of $A_V = 4.5$ by Nürnberger (2003).

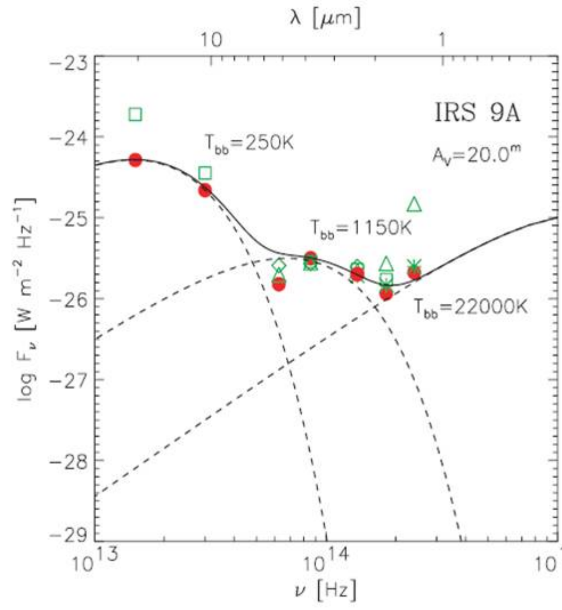

Figure 4: The SED dereddened by $A_V = 20$ mag, i.e. the combined foreground and intrinsic extinction, by Nürnberger (2003).

1.3 Emission components

The SED shows at least two components of different temperatures, the hotter one possibly corresponding to a dust evaporating inner edge of an accretion disk. If we correct the photometry for an adopted $A_V = 20$ mag, the photospheric spectrum of the central O-star is revealed. Moving the star in the $(J - K) - M_J$ diagram to the main sequence along the reddening vector indicates a mass of about 40 $M_\odot$ (Nürnberger 2003).

2 Observations and results

Observations were carried out with the MIDI mid-infrared beam combiner of the VLTI, and the aperture mask of the T-ReCS instrument at Gemini South. MIDI allows to measure the visibility as a function of wavelength between about 8 and 13 microns ($R = 35$), while T-ReCS allows to measure visibilities and (closure) phases for image reconstruction between all combinations of the 7-hole mask.

2.1 A compact hot component?

The MIDI visibility (46 m baseline) is near zero between 12 and 9 μm, but increases rapidly towards 8 μm. A simple geometrical model consisting of a hot (1000 K) ring component (57 mas diameter) and a warm (140 K) completely resolved component is shown in Figs. 5 and 6.

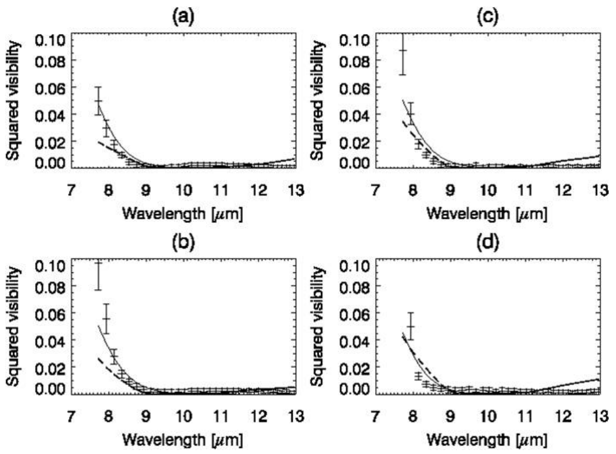

Figure 5: Visibility spectra measured at four epochs during the night of 2005, February 28, by MIDI. The solid line is a fit of a geometrical model, while the dashed line is a fit of the disk-envelope model # 3012790 of Robitaille et al. (2006).

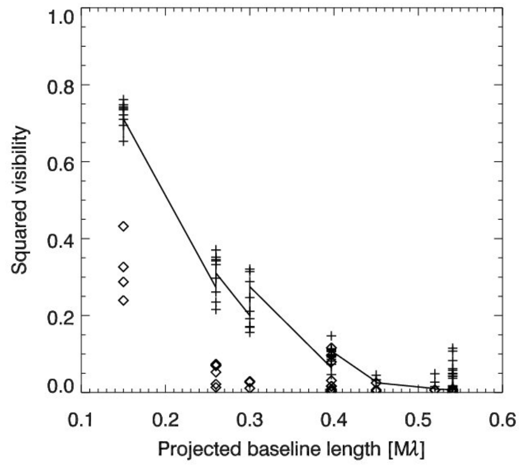

Figure 6: Visibility measurements as a function of baseline length measured with the aperture mask on Gemini South by the T-ReCS 11.7 micron camera. The solid line indicates the fit of the geometrical model, while the diamonds correspond to the physical disk-envelope model.

3 Modeling

3.1 Spherical dust distribution

Spherical dust distributions around MYSOs are very unlikely on theoretical grounds due to the fact that the very high luminosity of these stars would disperse the infalling envelope, preventing accretion to the final mass of the object. Despite of this, we attempted to fit a spherical dust envelope with a luminosity of 230 k$L_\odot$, $A_V = 29$ mag, and an inner radius $R = 170$ mas (1200 AU) where $T = 500$ K, and were able to reproduce the observed T-ReCS visibilities and the SED. The dust mass corresponds to one solar mass. However, this dust envelope would be completely resolved by MIDI. Only a flattened structure offers a direct view of the compact inner regions. Kraus et al. (2010) recently found evidence for such an accretion disk in another MYSO, while Krumholz et al. (2009) performed numerical simulations which indicate that disk accretion can overcome the Eddington limit.

3.2 An accretion disk at the center?

We are using the disk-envelope model of Whitney et al. (2003) to model the MIDI and T-ReCS visibilities, as well as the SED. Best-fitting models for the SED were selected from the grid published by Robitaille et al. (2006), and visibilities were computed. The best model is shown as a dashed line in the plots above. Only a disk model can explain the fact that significant correlated flux (from the hot inner regions) could be seen by MIDI despite the resolved envelope. A spherical model is excluded.

4 Conclusions and outlook

Our work can only be seen as a beginning of the investigation towards the unambiguous detection of a disk in the MYSO IRS 9A. Second generation VLTI instruments such as MATISSE will allow

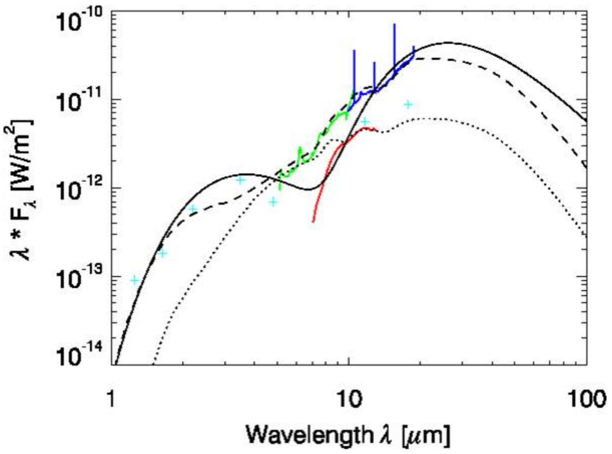

Figure 7: SED of model 3012790 for IRS 9A at 7 kpc distance (dashed line). The green and blue lines represent Spitzer SL and SH observations, respectively (Lebouteiller et al. 2008), while the red line is the MIDI spectrum. Solid line from the geometric model, dotted line for the MIDI aperture.

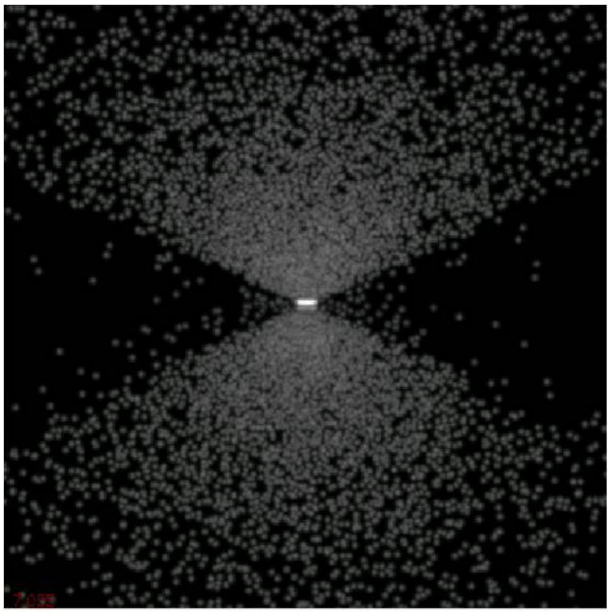

Figure 8: Image of the disk model with an envelope, inclined at 85 degrees.

imaging in the mid-infrared, dispensing with the need to use models to interpret the visibility data. We have shown that high angular resolution observations provide complementary information to mere modeling of the SED. A more comprehensive view should also include observations of outflows, indicative of ongoing accretion, and the possible Keplerian rotation of the flattened envelope or disk.

Acknowledgements

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