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INFRARED INTERFEROMETRY OF MASSIVE YOUNG STELLAR OBJECTS

W. J. de Wit,[1] M. G. Hoare,[1] R. D. Oudmaijer,[1] and T. Fujiyoshi[2]

RESUMEN

Se discuten la interferometría de AMBER y MIDI, además de observaciones de disco-simple en Subaru de objetos estelares masivos jóvenes. Las observaciones muestran tamaños de escalas lineales entre 10 y 100 UA como distancia promedio de nuestras fuentes.

ABSTRACT

We discuss AMBER and MIDI interferometry in addition to single-dish Subaru observations of massive young stellar objects. The observations probe linear size scales between 10 to 1000 AU for the average distance of our sources.

Key Words: infrared: stars — ISM: clouds — stars: early-type — stars: formation — techniques: interferometric

1. THE MYSO ENVIRONMENT

The massive YSO (MYSO) evolutionary phase is probably the earliest phase of a nascent hot star in which the various circumstellar phenomena can be identified and studied in detail at milli-arcsecond (mas) resolution in the infrared (IR). MYSOs lack (compact) H II regions from which one can infer a high mass accretion rate. Either the star is extended and thus relatively cool (Hosokawa & Omukai 2009), or the accretion quenches the H II region (Walmsley 1995). It is not clear which of these two scenarios applies. The ubiquitous presence of molecular outflows (Shepherd 2005), and in a few cases collimated jets (e.g. Cunningham et al. 2009) all point to ongoing accretion in such systems. Observations also indicate that disk structures are prominent features during the MYSO phase (e.g. Bik & Thi 2004). This evidence suggests that the mass accretion process proceeds (at least in parts) through a circumstellar disk, which is substantiated by numerical models (e.g. Krumholz et al. 2009). Disks are the likely source of an ionised wind with modest escape velocities traced by near-IR recombination lines (e.g. Bunn et al. 1995) and high-resolution radio observations (Hoare 2006). These defining components of the MYSO environment are all buried within a thick protostellar envelope, and they suggest a picture of massive star formation (SF) in many ways analogous to low-mass SF. We recall however that known MYSOs do not correspond to the most massive ZAMS O-type stars observed, but probably to early B or late O-type stars neglecting any multiplicity. Accreting stars with $M > 25\,M_{\odot}$ remain elusive. Here we present high-angular resolution observations of MYSOs in an attempt to understand their close environment on scales between 10 and 1000 AUs.

2. AT 1000 AU: THE ONSET OF ROTATION?

The protostellar envelope plays a critical role in massive SF. Observations can reveal whether it is in collapse or in force balance. Analysis of single-dish (sub)millimeter observations show that the density distribution at 10,000 AU is best described by a radial powerlaw with powers between −2.0 to −1.5 (e.g. Mueller et al. 2002). This could correspond to the static outer envelope of an inside-out gravitional collapse. In de Wit et al. (2009) we present a survey of 14 well-known MYSOs at 24.5 μm with the 8.2 meter Subaru telescope probing size scales of $\sim$ 1000 AU. We find that the resolved envelopes follow a relatively shallow density powerlaw with exponent −1. Such a powerlaw is consistent with the static outer part of an infalling logatropic sphere (McLaughlin & Pudritz 1997), however the 1000 AU size scale is too small. Instead, we suggest that the observations probe the region where rotation becomes dominant over infall and the transit occurs from a protostellar envelope to a disk.

3. AT 100 AU: MIDI OBSERVATIONS OF W33A

The VLTI-MIDI instrument is sensitive to 300 K continuum emission, which in the MYSO environment could either be located in a circumstellar disk,

[1]School of Physics and Astronomy, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK (w.j.m.dewit@leeds.ac.uk).

[2]Subaru Telescope, National Astronomical Observatory of Japan, Hilo, Hawaii, USA.

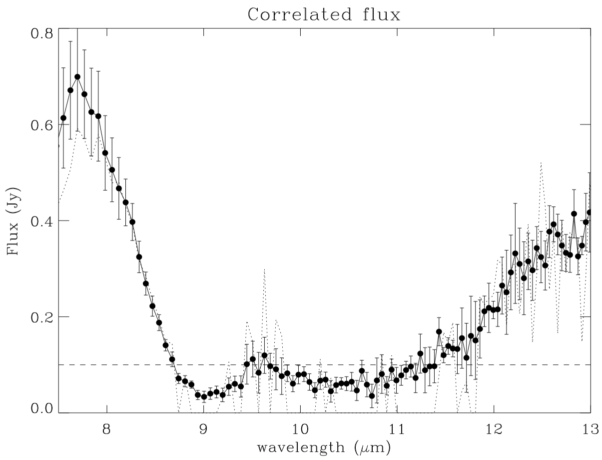

Fig. 1. MIDI correlated flux spectrum of W33A. Flux levels below the dashed line must be considered upper limits (from de Wit et al. 2007).

in the protostellar envelope or possibly in the outflow cavities (De Buizer et al. 2005). In Figure 1 we show the correlated MIDI flux spectrum of the MYSO W33A ($L = 4 \times 10^4$ $L_\odot$, 3.8 kpc). The spectrum is dominated by the exceptionally strong silicate absorption feature, indicating a very large dust optical depth. The corresponding visibilities reveal that the emitting region increases linearly with wavelength from 120 AU at 8 μm to 240 AU at 13 μm. This is consistent with temperature falling off with distance. Simultaneous modelling of the visibilities and observed spectral energy distribution with spherical dust radiative transfer models leads us to conclude (de Wit et al. 2007) that the data is consistent with a shallow dust density distribution (exponent -0.5 to -1.0). We also find that a better fit is obtained if we decrease the effective temperature of the central object to early A-type, making the underlying star effectively a supergiant. The latter result is similar to the MIDI result presented for the MYSO M8E-IR by Linz et al. (2008).

4. AT 10 AU: AMBER OBSERVATIONS OF G310

VLTI-AMBER is the three-beam recombiner operating in the JHK-bands delivering spectrally dispersed interferometric observables. We have obtained fringes of the MYSO G310 ($L = 2 \times 10^4$ $L_\odot$, 3.3 kpc) in the low spectral resolution mode on the U2-U3 and U3-U4 baselines. The visibilities correspond to a ring size of $\sim$ 2.5 mas or $\sim$ 8 AU at the adopted distance of G310. This size is consistent with that expected for a dust disk truncated by a sublimation temperature of 1000 K (see Monnier & Millan-Gabet 2002). The size of the emitting region is constant with wavelength. At K-band scattering of the particles is relatively efficient, and a large over-resolved component corresponding to the protostellar envelope is likely to be present (the resolved emission blobs generally seen in single dish images). However the AMBER fringes show that imaging information on scales as small as 10 AU are within reach, probing the important region where the mass accretion is actually taking place.

DISCUSSION

H. Zinnecker: *Are there any MYSOs for which all three presented types of data can be taken?* — We are working on that.

H. Zinnecker: *To what extend can you ignore the incidence of binaries in your fits to the 24.5μm data?* — In most cases the envelope is spherical to first order. However we have clear examples of multiple sources within a common envelope.

D. Setia Gunawan: *How significant is rotation in MYSO evolution, and how does this relate to disk formation/binary formation?* — Rotating structures have shown to be present in massive SF with molecular line observations. At what point and in how far this determines the formation of a disk/binary is not known.

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