INFRARED INTERFEROMETRY OF MASSIVE YOUNG STELLAR OBJECTS

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RESUMEN
En este trabajo, presentamos observaciones interferométricas y de plato unico de objetos estelares muy jóvenes y masivos, que fueron realizadas con los instrumentos AMBER y MIDI en el VLTI y con el telescopio Subaru. Dichas observaciones ofrecen la posibilidad de explorar las regiones centrales de estos objetos, cuyos tamaños lineales varian entre 10 y 1000 AU para las distancias típicas de estas fuentes.

ABSTRACT
We discuss VLTI 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: Stars: formation — Stars: early type — Infrared: stars — ISM: clouds — 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⊙ 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 gravitational 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 ~ 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 environ-
ment could either be located in a circumstellar disk, 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 $\mu$m to 240 AU at 13 $\mu$m. 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 ($-0.5$ 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 recombining 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).