The protostar within the large disk in M 17

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Abstract

For the first time, we resolve the elongated central infrared emission of the large accretion disk in M 17 (Chini et al. 2004) into a point-source and a jet-like feature that extends to the northeast. We regard the unresolved emission as to originate from an accreting intermediate to high-mass protostar. In addition, our images reveal a weak and curved southwestern lobe whose morphology resembles that of the previously detected northeastern one. We interpret these lobes as the working surfaces of a recently detected jet interacting with the ambient medium at a distance of 1700 AU from the disk centre.

The accreting protostar is embedded inside a circumstellar disk and an envelope causing a visual extinction of $A_V \geq 60$. This and its K-band magnitude argue in favour of an intermediate to high-mass object, equivalent to a spectral type of at least B4. For a main-sequence star, this would correspond to a stellar mass of 4 $M_\odot$.

Figure 1: *JHK* three colour composite of the young stellar cluster NGC 6618 and the star forming region in M 17 with a total FOV of about 5′.5 × 5′.8. The location of the large disk is indicated by a white frame covering an area of about 1′ × 1′.

Extinction estimates

We tried to estimate the extinction towards the disk centre by various different techniques. A lower limit comes from the NIR photometry giving $E(H-Ks) \geq 1.5$ which is equivalent to $A_V \geq 30 \pm 5$ neglecting IR excess or line emission.

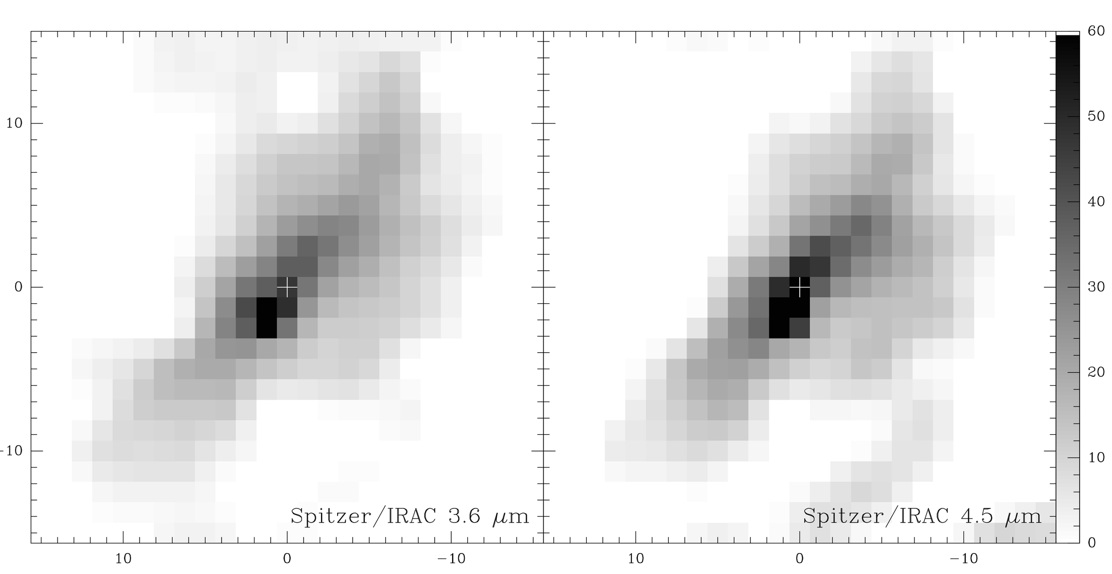

Figure 2: Visual extinction maps of the central 30″ × 30″ of the disk using Spitzer/IRAC data. The position of the central point-source is marked with a white cross. The scale is given in A_V. The extinction maximum is located ∼ 3″ southeast of the disk centre.

Another estimate relies on determining the optical depth without foreground or background extinction by measuring the ratio of a uniform background illumination and the attenuated radiation passing through the absorbing material (Siebenmorgen & Krügel 2000). The analysis of Spitzer/GLIMPSE archival data (see Fig. 2) gave $A_V = 60 \pm 10$ – averaged over a pixel of 1″.2 squared – for the entire line of sight through the disk, half of which is expected to be the extinction to the disk centre coming from the disk alone. A similar result of $A_V = 27$ was given by Steinacker et al. (2006). Another $A_V = 35 \pm 5$ of foreground extinction, mostly originating from the surrounding matter in M 17, must be added to this value. This results in a strong total visual extinction of $A_V = 62 \pm 5$ towards the point-source in the centre of the disk.

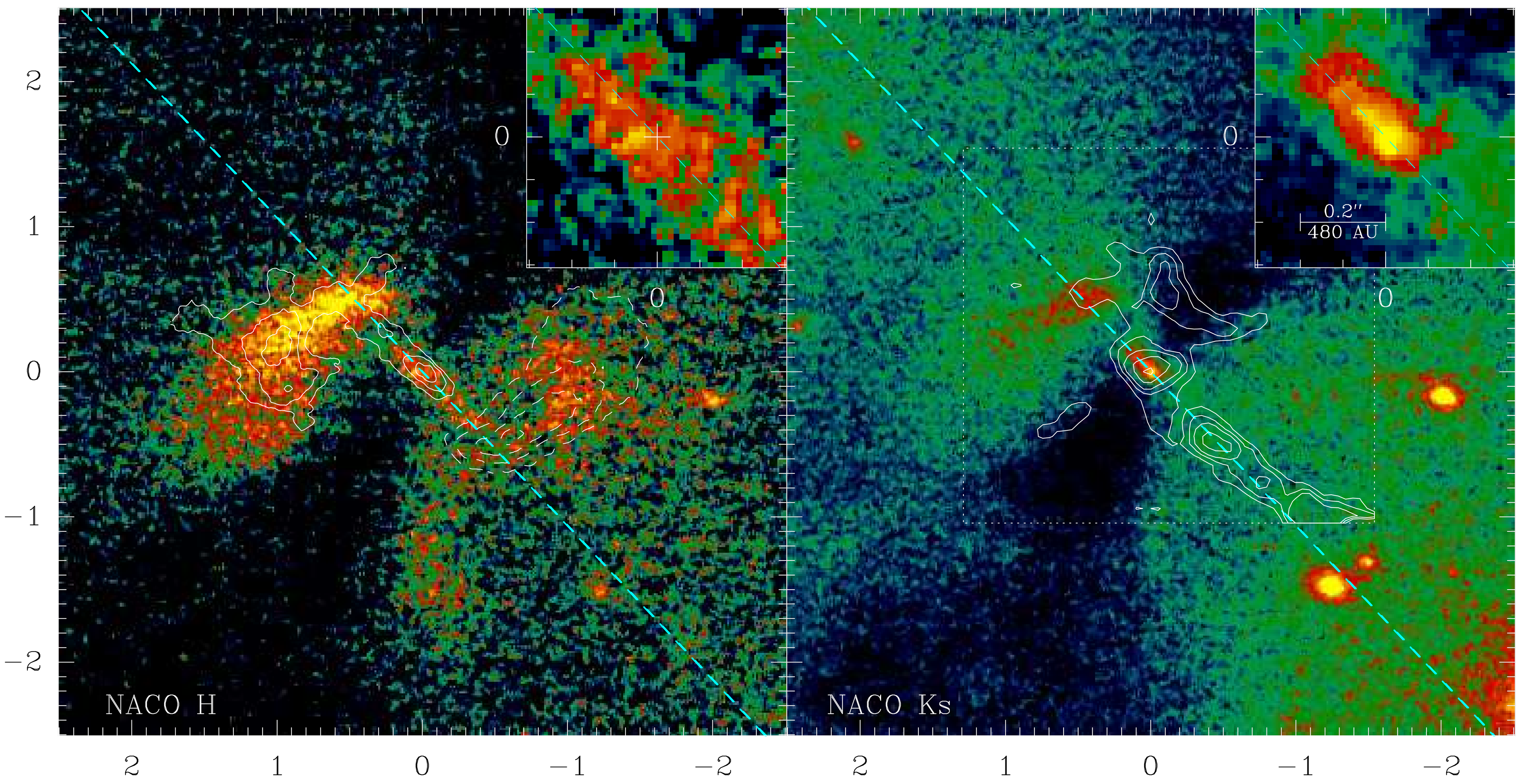

Figure 3: NACO/VLT infrared images of the inner region (6″ × 6″) of the M 17 disk silhouette centred on R.A. = 18^{h}20^{m}26^s.191 and Dec. = −16°12′10″.46 (J2000). The inserts show the central 0″.6 × 0″.6. Left: *H*-band image showing a weak bent lobe to the southwest of the disk. To visualise its symmetry with respect to the known northeastern lobe, we have superimposed the contours of the two outflow lobes rotated by 180° around the central source which we define as the symmetry centre; solid contours refer to the southern lobe, dashed contours represent the northern lobe. The dashed blue line marks the suggested jet axis as determined by the orientation of the detected tail with respect to the point-source. Right: *Ks* image resolving the central channel into a point-source and a fainter tail extending to the northeast. The southwestern lobe is invisible in the *Ks*-band. The contours denote the H_2 1 − 0 S(1) line emission of the jet at λ = 2.12 μm as measured with SINFONI/VLT (Nürnberger et al. 2007).

The protostar in the disk centre

The previously unresolved elliptical infrared emission in the centre of the disk is now resolved into one point-source and a tail that extends to the northeast (see Fig. 3, insert of right panel). We are confident to have detected the protostar and the base of the northeastern counterpart of the southwestern protostellar jet (Nürnberger et al. 2007).

At an assumed distance of 2400 pc (see poster by Hoffmeister et al.), the photometry of the suspected protostar ($Ks = 19.3 \pm 0.1$) together with the extinction estimates argues in favour of a stellar source being equivalent to a spectral type of B4 or earlier. For a main-sequence star, this would correspond to a stellar mass of 4 $M_\odot$ (Blum et al. 2000).

H-band excess of the NE lobe

A considerable *H*-band excess of the northeastern lobe can be explained either by a combination of light scattering and extinction or by line emission. Together with molecular hydrogen, [Fe II] is the main coolant of shocked gas in the NIR (Caratti o Garatti et al. 2006).

However, apart from a spurious detection ahead of the northeastern lobe, our narrow-band image (see Fig. 4, dashed contours) shows a strong concentration of [Fe II] emission towards the disk centre. This seems to be a typical phenomenon for many protostellar jets (Itoh 2001; Davis et al. 2006).

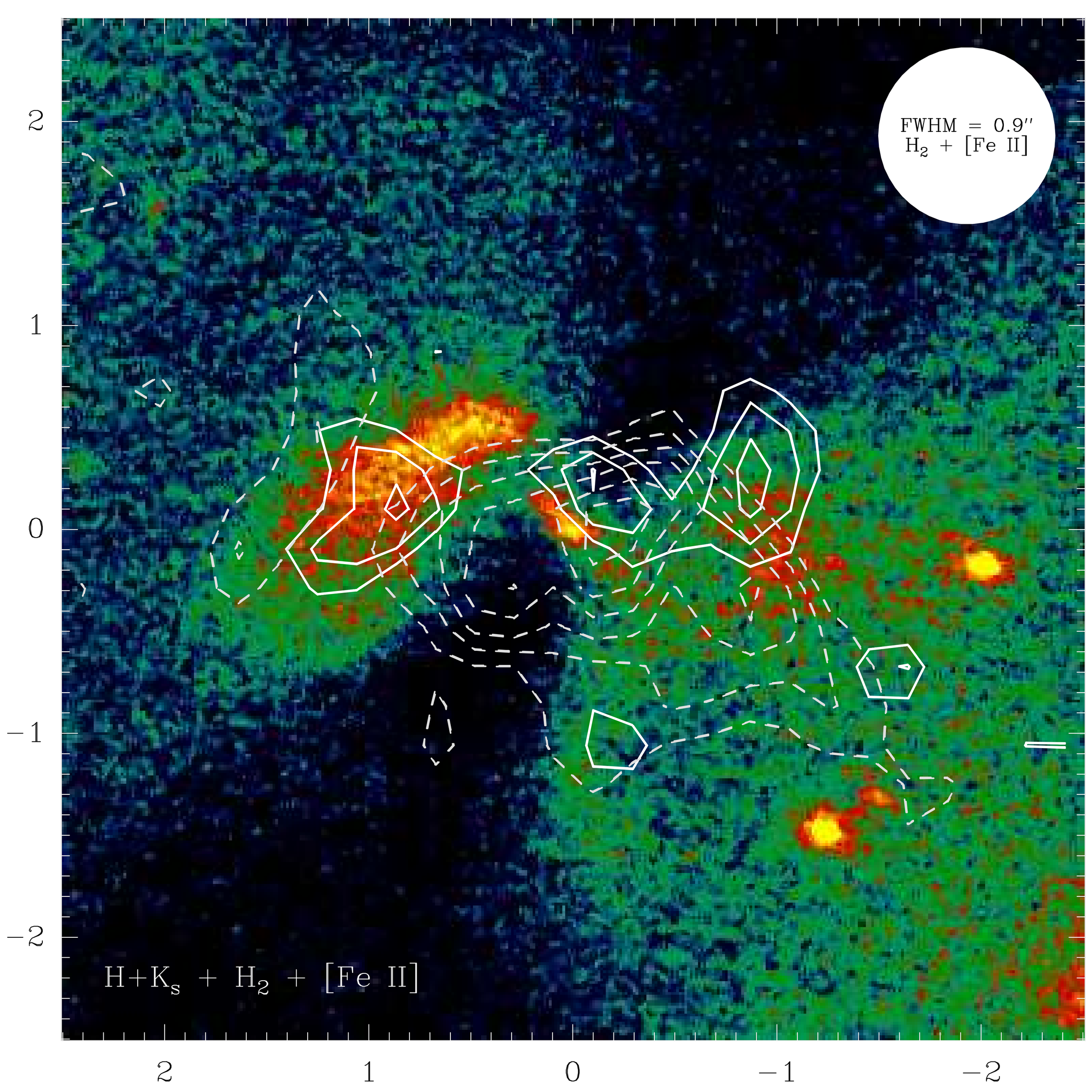

Figure 4: Overlay of a combined NACO *H* + *Ks* image with contours of H_2 (λ = 2.12 μm, white solid) and [Fe II] (λ = 1.64 μm, grey dashed) obtained with SOFI at the NTT. While the H_2 emission is mainly associated with the lobes and the disk, the [Fe II] emission is concentrated at the disk centre.

Detection of a SW counter-lobe

Our *H*-band image shows a weak southwestern emission lobe that displays a point-symmetry to the northeastern lobe with respect to the suspected protostar (see Fig. 3, left panel). We interpret these phenomena as the working surfaces of the protostellar jet as detected by Nürnberger et al. (2007). They are located at a projected distance of 1700 AU from the symmetry centre.

A PDR on the disk surface

The H_2 emission inside the disk, in particular at its surface, indicates the presence of a PDR (photo-dissociation region) excited by FUV photons (Tielens & Hollenbach 1985). Its concentration to the disk centre suggests an internal rather than external trigger. Model calculations adopted from Diaz-Miller et al. (1998) support a FUV source of $T_{\rm eff}$ = 15 000 K which is equivalent to a star of spectral type B4 (Blum et al. 2000) which is in good agreement with the previous estimate. A visual extinction of A_V = 64 is required to achieve the measured *K*-band magnitude.

Conclusions

1. The central elliptical emission could be resolved for the first time into a point-source and a tail that extends to the northeast. We interpret this detection as a single protostar accompanied by a jet.
2. Based on our various extinction estimates towards the deeply embedded protostar, we find a lower limit of about A_V = 60.
3. In combination with the observed 2.2 μm flux, this suggests a star equivalent to a spectral type of at least B4 corrresponding to a stellar main-sequence mass of 4 $M_\odot$.
4. Apart from the southwestern jet detected by Nürnberger et al. (2007), we find evidence for a counter-jet towards the northeast. Along with the newly detected southwestern lobe the outflow pattern of the disk is fairly symmetric.

In summary, the new evidence for a luminous stellar source at the disk centre, the pair of symmetric working surfaces and the elongated H_2 emission orientated along the jet axis corroborate the suggestion by Chini et al. (2004) that an intermediate to high-mass protostellar object is in the process of accretion.

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