GEMINI T-ReCS AND MICHELLE OBSERVATIONS OF MASSIVE YOUNG STELLAR SOURCES WITH MID-INFRARED OUTFLOWS AND JETS.

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It has been proposed that linear methanol maser distributions arise in circumstellar accretion disks around massive young stellar sources (i.e., [1]). Since direct detection of these accretion disks has proved difficult, another way to test the disk hypothesis is to search for outflows perpendicular to the methanol maser distributions. Wide-field images of a sample of sites of linearly distributed methanol masers using in the 2.12 µm H_2 line as the outflow diagnostic were obtained by [2]. Surprisingly, the H_2 emission in 89% of the fields was not distributed perpendicular to the maser distributions as expected, but instead parallel, implying perhaps that methanol masers may be delineating outflows rather than circumstellar accretion disks.

Recent follow-up observations in the mid-infrared (5-25 µm) of these massive young stellar sources with maser emission have shown a surprising result: some show evidence of mid-infrared emission from outflows and jets (i.e., [3]). There are three varieties of sources that show evidence that the mid-infrared emission is indeed tracing outflows and jets. First, some sources that have H_2 outflows and methanol maser distributions at the same position angle are also found to be elongated at that same position angle in the mid-infrared. Such a source is G318.95-0.20 and is described below. Second, some sources have more resolved mid-infrared structures that appear morphologically similar to H_2 outflows, and this smaller scale outflow exists at the same position angle as some other larger-scale outflow indicator like CO. An example of such a source is NGC 7538 IRS 1. Finally, there are sources that have mid-infrared emission coincident with and tracing known outflow structures seen at other wavelengths. We present an example of this type of source with G35.20-0.74.

Though outflows with thermal infrared emission have been observed previously at lower resolution [3,4,5], thanks to the increase of facility-class mid-infrared imagers on large aperture telescopes (8-10m), we are achieving high resolutions in the mid-infrared (~0.25-0.60") that now allow us to see the detailed morphologies of the mid-infrared outflows around these young stellar sources.

The association of masers and mid-infrared emission with outflows and/or jets from young massive stellar sources is exiting because little is known about the massive star formation process. Direct associations of outflows and jets with individual massive stars are few. Outflows from massive stars may demonstrate that they form by accretion processes similar to low mass stars.

G318.95-0.20: Previous observations of the source G318.95-0.20 have shown that this young stellar object lies at the center of extended H_2 (2.12 µm) emission at an angle of –48º that is thought to trace an outflow [2]. This source is also associated with methanol masers that exist in a linear distribution. The mid-infrared observations of this region using T-ReCS on Gemini South show that the masers are coincident with the peak of the mid-infrared source. However, as one can see in Figure 1, the mid-infrared emission of G318.95-0.20 is extended at an angle comparable to both the H_2 outflow angle and the methanol maser distribution position angle. From these observations it is concluded that the methanol masers and mid-infrared emission are both likely related to the H_2 outflow. The mid-infrared emission is thought to be coming from the circumstellar envelope that is being elongated by the outflow and subsequent dust entrainment.

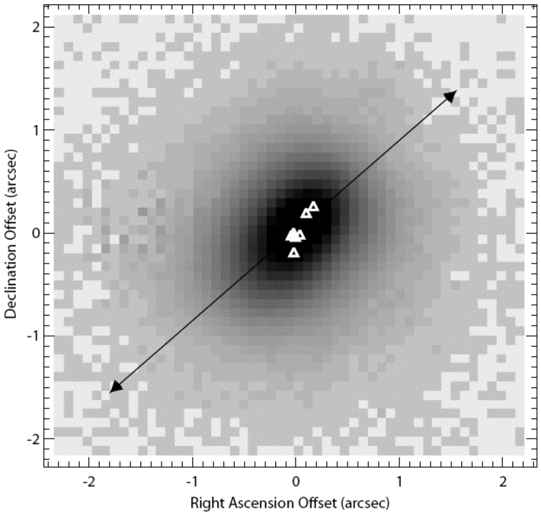

Figure 1. G318.95-0.20 seen at 11.7 µm. The locations of the methanol maser spots (white triangles) from [1] are also given. These masers are linearly distributed at a similar position angle as the H_2 outflow orientation (arrows) seen by [2]. The mid-infrared emission is elongated at the outflow position angle.

NGC7538 IRS 1: High-resolution mid-infrared images of the high-mass protostar NGC 7538 IRS 1 using Michelle on Gemini North were obtained by [6].

The circumstellar dust associated with this source is extended on both large and small scales (Figure 2). The position angle of the large-scale mid-infrared emission is similar to the position angle of the CO outflow in this region that appears to be centered on IRS 1 [7]. It has been suggested that the large-scale extended mid-infrared emission is coming from dust heated on the walls of the outflow cavities near the source [6]. The linearly distributed methanol masers at this location are also at a similar position angle indicating that they may be related to the outflow, though it is believed by [8] that they trace a circumstellar disk. IRS 1 is also elongated in the mid-infrared on a smaller scale, and this elongation is near perpendicular to the axis of the outflow (and the linearly distributed methanol masers) and may trace the disk collimating the outflow.

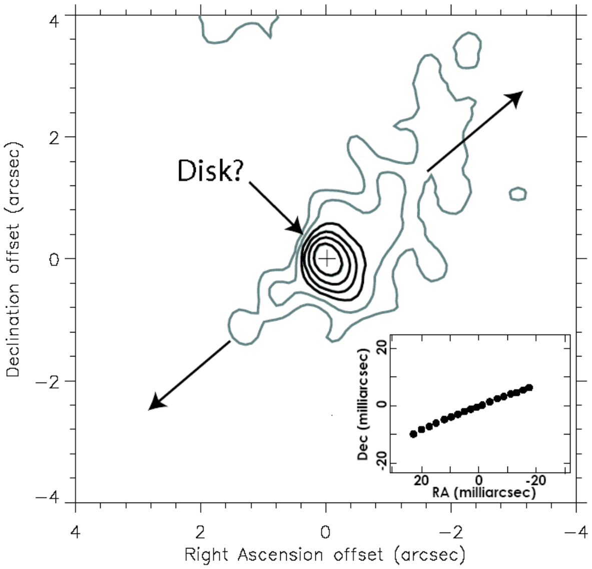

Figure 2. A contour plot of the deconvolved 18.3 µm emission from NGC7538 IRS 1 from [6]. The position angle of the CO outflow is given by the arrows. The cross marks the location of the methanol masers, which are linearly distributed (inset) and claimed by [8] to be tracing a circumstellar disk. The coincidence of position angle between the maser distribution, CO, and mid-infrared lead to the conclusion that they are all outflow related. The inner contours of the mid-infrared emission may trace the disk collimating the outflow.

G35.20-0.74: The cm radio continuum emission at this site was resolved by [9] into a north-south bipolar radio jet coming from a UC HII region. Follow-up observations by [10] with higher resolution showed that the radio jets break up into knots of emission running in the north-south direction.

The mid-infrared observations using T-ReCS on Gemini South of this region reveal a spectacularly extended source that starts at the central UC HII region and extends northward in the direction of the northern radio outflow knots (Figure 3). The mid-infrared images also look very reminiscent of a monopolar outflow lobe like those seen in near-infrared H_2 emission for low-mass young stellar objects.

Because the filter bandpasses do not encompass any outflow diagnostic lines (like H_2), it is concluded that this source is dominated at wavelengths >3 µm by reradiated thermal dust emission from the outflow cavity. It also appears that a majority of the masers exist on the walls at the base of this outflow cavity (Figure 3).

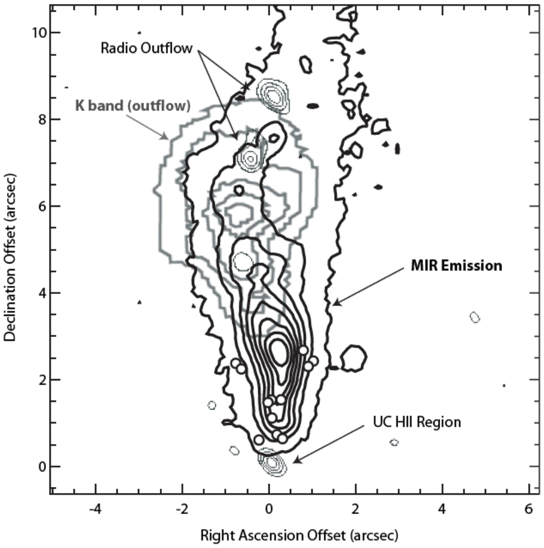

Figure 3. The outflow from G35.20-0.74. The outflow was established by observations in radio continuum emission (thin black; [10]) and in the near-infrared at K (thick gray; [4]). Clearly seen is the outflow cavity of this source in the mid-infrared at 11.7 µm (thick black) emanating from the UC HII region at the bottom of the figure. Water masers (circles) are in a V-shape and trace the walls of the outflow as seen in mid-infrared emission.

References: [1] Norris, R. P., et al. (1993) *ApJ, 412*, 222-232. [2] De Buizer, J. M. (2003) *MNRAS, 341*, 277-298. [3] De Buizer, J. M., et al. (2005) *ApJS, 156*, 179-215. [4] Fuller, G. A., Zijlstra, A. A., & Williams, S. J. (2001) *ApJL, 555*, L125-128. [5] Noriega-Crespo, A. et al. (2004) *ApJS, 154*, 352-358. [6] De Buizer, J. M. & Minier V. (2005) *ApJL, 628*, L151-154. [7] Davis, C. J., et al. (1998) *AJ, 115*, 1118-1134. [8] Pestalozzi, M. R., et al. (2004) *ApJL, 603*, L113-L116. [9] Heaton, B. D. & Little L. T.(1988) *A&A, 195*, 193-197. [10] Gibb, A G., et al. (2003) *MNRAS, 339*, 1011-1024.