NGC 3576 IRS 1 in the Mid Infrared

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**Abstract.** We present the results of high-resolution mid-infrared observations of the source NGC3576 IRS 1. Near diffraction-limited images were taken at the Gemini South Observatory through OSCIR’s filters N (10.8 µm), 7.9, 9.8, 12.5 and IHW18 (18.2 µm). The source IRS1 was resolved into 3 sources for the first time at mid-infrared wavelengths. For each source we constructed the SED from 1.25 to 18 µm, as well the color temperature and the spatial distribution of the dust in the region. The optical depth of the silicate absorption feature at 9.8 µm is presented also.

1. Introduction

The formation mechanism of massive stars is essentially unknown. This is mostly due to observational difficulties in finding and establishing an evolutionary se-

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2 This paper is based on observations obtained with the mid-infrared camera OSCIR, developed by the University of Florida with support from the National Aeronautics and Space Administration, and operated jointly by Gemini and the University of Florida Infrared Astrophysics Group.
quence for young stellar objects (YSOs). It is believed that during the accretion phase, YSOs remain heavily enshrouded in dusty cocoons, behind hundreds of magnitudes of extinction at visual wavelengths (even at near-infrared wavelengths for the earliest phases).

A very interesting group of YSOs has been identified in the Galactic giant HII regions (GHII) M17 (Hanson, Horwarth & Conti 1997), W43 (Blum, Damineli & Conti 1999), W42 (Blum, Conti & Damineli 2000), W31 (Blum, Damineli & Conti 2001) and NGC 3576 (Figueredo et al. 2002). These are luminous YSOs with excess emission in the K band and have color indexes H-K > 2. J, H and K spectra of these objects typically show a featureless continuum. In some cases the CO 2.3 \( \mu m \) bandhead is seen in emission or absorption, and in others FeII and/or H\(_2\) are seen in emission.

Figueredo et al. (2002) identified two massive YSO candidates in the position of IRS 1 in NGC 3576. This source was discovered by Lacy, Beck & Geballe (1982) and it was recently observed at 10 \( \mu m \) by Walsh et al. (2001), but none of their images have enough spatial resolution to resolve the source.

2. Observations

Observations were obtained at the Gemini South Observatory 8-m telescope on December 4th, 2001. OSCIR is based on a Rockwell 128\( \times \)128 pixel Si:As BIB detector, with a 0.089 arcsec/pixel plate scale at Gemini. The total field of view of the camera is 11\( \times \)11 arcsec and the spatial resolution (FWHM of the PSF star) is \( \sim \)0.5 arcsec. The images were taken through the wide N-band filter (10.8\( \mu m \)) and IHW18 (18.2 \( \mu m \)) and the 7.9, 9.8 and 12.5 \( \mu m \) narrow filters. Flux calibration was performed by taking the flux densities of the mid-infrared standard star \( \alpha \) CMa observed during the night as part of the baseline calibration program. The uncertainty of these procedures is estimated to be \( \sim \)10\%, which is good enough for our purposes.

All images presented have on-source exposure time of 46 seconds, except the N-band image which has 40 seconds. Background and sky subtraction was done via the standard chop and nod technique.

3. Results

The field of NGC 3576 IRS 1 is shown in the Figure 1, for the N and IHW18 bands. IRS 1 has been resolved into 3 sources embedded in extended emission. All images were smoothed by convolving each image by the corresponding normalized PSF star fitted from the standard star using a Fourier transform.

Figure 2 shows the spectral energy distribution (SED) of each source. The JHK fluxes are from Figueredo et al. (2002), the L-band flux is from Moneti (1992). The NIR-to-MIR SEDs are very similar to the results found for a group of less massive AeBe stars by Hillenbrand et al. (1992). The stars of this group (called group II) have SEDs with infrared excess and are supposed to be young stars with intermediate masses (\( M \leq 10 M_\odot \), average spectral type A5) still accreting. The infrared excess is attributed to a dense dusty accretion disk surrounding the young stars.
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Figure 1. *Left:* The N-band image of IRS-1. The contours are at 0.01, 0.025, 0.05, 0.1, 0.2, ..., 0.5 Jy/". *Right:* The 18µm image of IRS-1. The contours are at 0.044, 0.088, 0.13, 0.17, 0.2, 0.27, 0.35, 0.4 Jy/". North is up, East is left for both images. Each image is 11×11 arcsec.

Figure 2. *Left:* NIR-to-MIR SED for each source identified in the IRS 1 position. *Right:* The SED constructed from the fluxes measured at mid infrared. The dashed line is the projected free-free emission of the gas from De Pree, Nysewander & Goss (1999), assuming $S_{\nu} \propto \nu^{-1}$. 
Figure 3. **Left:** The map of the silicate absorption at IRS-1 position. The darker is the region, the strongest is the absorption. The contour at the source #60 position indicates where the absorption turns into emission. **Right:** The dust color temperature map of IRS-1. The contour levels are represent temperatures of 160, 180, 200, ..., 280 K. Both images are 5.8×5.8 arcsec.

Figure 3 shows the spatial distribution of the dust, as well as, its color temperature map. The map at the left was obtained dividing the calibrated image taken at 9.8 µm by the 7.9 µm image. From this map, we have calculated the optical depth of the silicate absorption feature and we found $\tau_{9.8}=3.7$. The right panel is the dust color temperature map which was calculated from the ratio of the 7.9/18 µm images. From this map we can see the dust temperature associated with each source: $T\sim280$K (#50), $T\sim210$K (#48) and $T<160$K (#60).

4. **Summary**

We presented high-resolution mid-infrared images of NGC 3576 IRS 1, that has been resolved into 3 sources for the first time at mid-infrared wavelengths. The SEDs of each source were constructed from 1.25 to 18 µm with data taken from literature. Each SED shows increasing fluxes toward to longer wavelengths. Hillenbrand et al. (1992) found similar SEDs for a group of less massive young stars in process of accreting mass via an accretion disk embedded in a dusty cocoon. This similarity suggests the same interpretation for our results. Finally we presented maps of dust distribution, temperature and optical depth as well.

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