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Abstract

OH/IR stars are evolved stars exhibiting large infrared excess as well as prominent OH maser emission. The vast majority of this heterogeneous object class are highly-evolved low- and intermediate-mass stars stars ascending the upper part of the asymptotic giant branch (AGB). Thus, these stars are in the final phase of their AGB evolution which is characterized by intensive mass loss with mass-loss rates that can reach up to $10^{-4}\,\mathrm{M}_\odot$. This high mass loss leads to the development of an extended, usually optically thick dusty circumstellar envelope which can be well studied with infrared-interferometric observations. Here, we present mid-infrared long-baseline interferometric measurements of a small sample of highly dust-enshrouded OH/IR stars obtained with the VLTI/MIDI instrument.

Observations

The observations presented here were carried out with MIDI, the mid-infrared interferometric instrument of ESO's VLTI at Cerro Paranal, between February and August 2006 (observing periods P76 and P77). All measurements were obtained using the auxillary telescopes (ATs) of the VLTI and are among the first observations carried out with MIDI and the ATs. Since all sources are fainter than $V = 14^{\mathrm{m}}$, an external source within $1''$ distance from the science targets had to be used for Coudé guiding. A summary of the MIDI observations is given in Tab. 1.

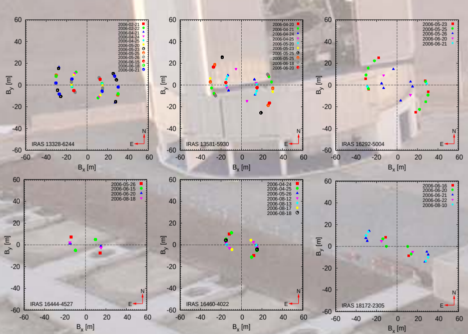

Figure 1: (u, v) coverage corresponding to the MIDI observations of our 6 sample targets.

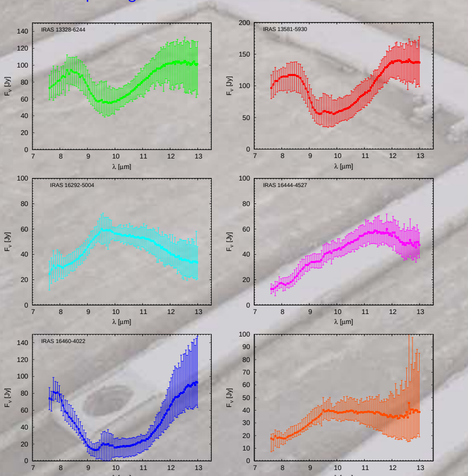

Figure 2: Averaged MIDI spectra of our 6 sample sources. 3 sources (IRAS 13328-6244, IRAS 13581-5930, and IRAS 16460-4022) show a deep silicate absorption feature, indicating a very optically thick circumstellar environment composed of oxygen-rich dust. In 2 other sources (IRAS 16292-5004 and IRAS 18172-2305), the silicate feature is seen in emission, thus indicating a less optically thick envelope of oxygen-rich dust. In the case of IRAS 16444-4527, the MIDI spectrum peaks around 11.5 μm. Here, the interpretation of the nature of the infrared excess is less straightforward.

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Poster presented at the ESO workshop *Science with the VLT in the ELT Era*, October 2007, Garching

IRAS number	RA [2000]	DEC [2000]	obs. time [2006]	N	B_{p} [m]	P.A. [°]
13328-6244	13:36:19	-62:59:19	Feb. – Jun.	21	13.4 – 31.9	42 – 120
13581-5930	14:01:40	-59:44:34	Apr. – Jun.	17	13.6 – 32.0	20 – 112
16292-5004	16:33:00	-50:10:56	May. – Jun.	12	13.5 – 32.0	14 – 102
16444-4527	16:48:05	-45:32:55	May. – Aug.	4	11.0 – 16.0	63 – 117
16460-4022	16:49:34	-40:27:39	Apr. – Aug.	10	10.2 – 16.0	42 – 115
18172-2305	18:20:19	-23:03:51	Jun. – Aug.	9	14.0 – 32.0	53 – 90

Tab. 1: Overview of the MIDI measurements of our small sample of OH/IR stars. N is the total number of MIDI observations. The B_{p} and P.A. columns give the range of projected baselines and position angles covered by the MIDI measurements.

Figs. 2 and 3 show the MIDI observables (spectra and visibilities) obtained for our 6 sample sources. The calibrated MIDI spectra in Fig. 2 are the spectra derived from an average over all recorded MIDI spectra. The absolute calibration of the spectra was performed using the absolutely calibrated spectra of the calibrator stars given by Cohen et al. (1999). For the reduction of the MIDI data, we used both the MIA package developed at the MPIA in Heidelberg (Leinert et al. 2004) and the EWS package developed at Leiden Observatory (Jaffe et al. 2004). We found very good agreement between the results obtained with both softwares. In Figs. 2 and 3, the results obtained with EWS are shown. To give an idea of the apparent size of our 6 targets across the N band, in Fig. 4 we show the equivalent Gaussian FWHM diameters obtained from a simultaneous fit of all measurements.

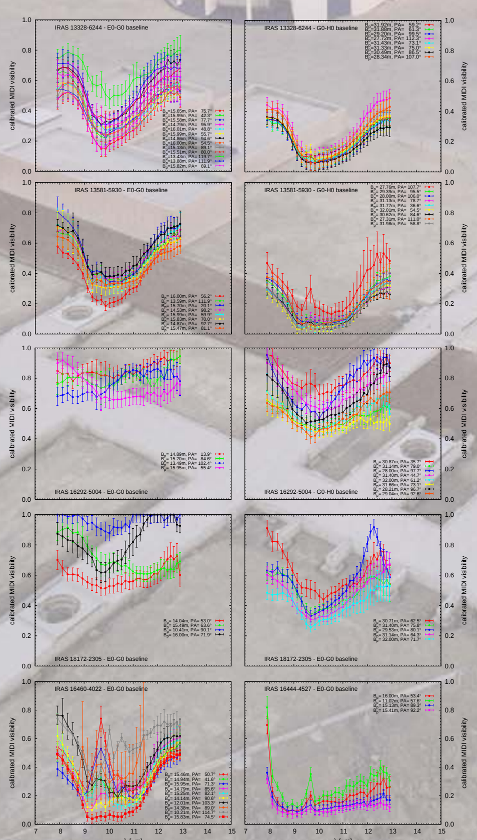

Figure 3: MIDI visibility measurements as a function of wavelength for all 6 sample targets. For IRAS 13328-6244, IRAS 13581-5930, IRAS 16292-5004, and IRAS 18172-2305 observations with both the E0-G0-16m and the D0-G0-32m baseline have been obtained. For IRAS 16444-4527 and IRAS 16460-4022 measurements with only the E0-G0-16m have been carried out. The peaks around 9.7 μm visible in some measurements are not object-intrinsic, but related to an imperfect compensation of the atmospheric ozone feature.

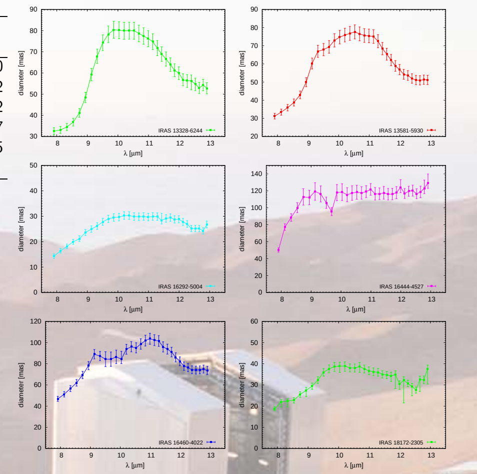

Figure 4: Wavelength-dependence of the apparent size of our 6 targets across the N band. For each individual target, the panels show the equivalent Gaussian FWHM diameters obtained from a simultaneous 1-D fit of all MIDI visibility measurements. Since the true center-to-limb variation can show strong deviations from a Gaussian shape, the diameters shown in this figures can give just a rough idea of the N-band sizes of the objects.

Modeling

We recently started to carry out radiative transfer calculations using the 1-D code DUSTY (Ivezić & Elitzur 1995) and the 2-D Monte Carlo code presented in Ohnaka et al. (2006) to simultaneously model the wavelength dependence of the visibility across the N band and the mid-infrared spectrum of our sample stars as they have been observed with VLTI/MIDI. An example of our 1-D modeling is illustrated in Fig. 5.

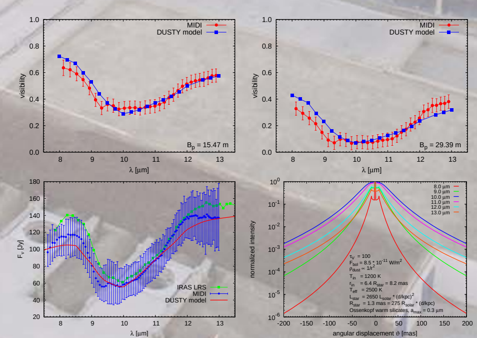

Figure 5: Comparison of the MIDI observations of IRAS 13581 with a 1-D radiative transfer model obtained with DUSTY. The upper two panels show the comparison of model (blue squares) and observations (red bullets with error bars) for two of our MIDI visibility measurements with the E0-G0-16m and D0-G0-32m baseline, respectively. The comparison of the N-band model spectrum (solid red line) with the calibrated MIDI spectrum (blue bullets with error bars) and IRAS LRS spectrum (green squares) is shown in the lower left panel. For the absolute flux calibration, we used the spectra of Cohen et al. (1999). The lower right panel shows the radial model intensity profiles for different wavelengths across the N band. The labels in the lower right panel give some basic model parameter values: r_{in} and T_{in} are the radius and temperature at the inner dust shell boundary, and τ_V is the optical depth at $0.55\,\mu$m.

References

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