A mid-IR study of the circumstellar environment of Herbig Be stars^{★,★★}

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ABSTRACT

Context. The study of the formation of massive stars is complicated because of the short times scales, large distances, and obscuring natal clouds. There are observational and theoretical indications that the circumstellar environment of Herbig Be (HBe) stars is substantially different from that of their lower mass counterparts, the T Tauri and Herbig Ae stars.

Aims. We map the spatial distribution and mineralogy of the warm circumstellar dust of a sample of HBe stars. We compare our results to a sample of less massive Herbig Ae stars.

Methods. We used literature photometry to obtain optical extinctions and stellar parameters of the targets. We obtained *N*-band imaging and long-slit spectroscopic data with the VISIR instrument at the VLT and we analyzed these data. We performed photometry of the images and extracted spatial information. We corrected the spectra for extinction and performed mineralogical fits. We fitted Gaussian profiles to characterize the spatial extent of the spectra along the VISIR slit.

Results. We find that the mid-infrared (IR) emission of the HBe stars is typically characterized by a circumstellar disk that efficiently reprocesses a substantial portion of the stellar flux. The mid-IR flux levels, the spatial compactness, and the dust composition are quite similar to those of the Herbig Ae stars. We find upper limits to the full-width-at-half-maximum (FWHM) size of the mid-IR emission of ~ 500 AU. The main differences with the lower mass stars are the lower overall IR excess with a greater variety in shapes, the weaker PAH reprocessing power, and the lack of a silica-forsterite relation. The discrepancies between VISIR and IRAS photometry, the far-IR contributions and the large PAH sizes of HBe stars are attributed to natal clouds.

Conclusions. Our results suggest that the Herbig Be disks are flatter than those around lower mass stars and they are likely truncated from the outside by photoevaporation.

Key words. stars: formation – stars: pre-main sequence – protoplanetary disks – stars: variables: T Tauri, Herbig Ae/Be – infrared: stars

1. Introduction

The formation and early evolution of massive stars are not well understood. Direct observations of these processes are hampered because massive stars form on a much shorter time-scale than lower mass stars. In their earliest infancy they are hidden behind huge amounts of optical extinction. The nearest massive young stars are also more distant than their lower-mass counterparts. The much higher luminosity and intense UV radiation field of young massive stars strongly affects their environment at very early times. The geometry and composition of the gas and dust around the star may differ from that seen in lower mass

stars, as may the time-scale on which this circumstellar material dissipates. Massive stars are also known to have prominent stellar winds (e.g. [Vink et al. 2001](#)), which complicates the picture even more. The lack of a long pre-main-sequence phase, during which the circumstellar material slowly dissipates and a planetary system may form, marks an important qualitative difference between massive and lower mass young stars. This being said, the upper mass for stars to form planetary systems is not known.

Herbig Be (HBe) stars are a subclass of Herbig Ae/Be stars, intermediate-mass young stars first described as a group by [Herbig \(1960\)](#). They represent the more massive stars in the group, with zero-age main-sequence (ZAMS) masses up to roughly $20 M_{\odot}$. Many observational studies have described the properties of Herbig Ae/Be stars (see e.g. [Natta et al. 2000](#)). A picture has emerged in which the lower mass Herbig Ae (HAe) pre-main-sequence stars have disks that can be considered as scaled-up versions of disks found around the solar mass T Tau pre-main-sequence stars. These disks are formed during

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the collapse and proto-stellar phase as a result of angular momentum conservation, and are the site of planet formation. The dust in these gas-rich disks has undergone substantial settling and grain growth, which can be inferred from the large mass in cold, millimeter sized grains detected in many systems (Natta et al. 2007). The warm disk surface layers in many H Ae stars also show evidence for grain growth and crystallization in the mid-infrared (IR) (e.g. van Boekel et al. 2003; van Boekel et al. 2005; Schegerer et al. 2006; Kessler-Silacci et al. 2006).

There are observational indications that this qualitative picture no longer applies for higher mass stars. Searches for a reservoir of large, cold grains in more massive HBe stars have shown that the mass in cold grains is substantially lower than that in lower mass stars (Fuente et al. 2003). In a more recent study, Alonso-Albi et al. (2009) show that the disk mass in some HBe stars is only on the order of 10 per cent of the total envelope mass; they propose that the strong UV radiation field of the central star causes rapid photo-evaporation of the outer disk, leaving a relatively small inner disk. Observations of the inner disk structure also suggest differences between high- and low-mass stars. Monnier et al. (2005) showed on the basis of near-IR interferometry that the inner radius of disks in lower mass stars is set by the dust sublimation radius and that the inner cavity is optically thin. For the high-luminosity B0-B3 stars, however, smaller inner dust radii are found, possibly implying optically thick gas in the inner regions. A detailed study of the geometry of the disk surrounding the B1.5 star MWC 297 showed that the disk is very compact and may extend to (close to) the stellar surface, with little or no evidence for an inner cavity (Acke et al. 2008).

Theoretical studies of disk evolution in massive young stars predict that the outer disk evaporates on short time-scales while the inner disk can survive longer (e.g. Hollenbach et al. 1994; Gorti & Hollenbach 2009). Disk evaporation time-scales are found not to vary with stellar mass for masses lower than $\sim 3 M_{\odot}$ and disk lifetimes are on the order of 10^6 yr. However, for the more massive stars the intense UV radiation field evaporates the disks on time-scales on the order of 10^5 yr. Translating this mass into a spectral type at the ZAMS, substantial changes in disk lifetime and disk geometry are expected in the mid-B spectral range.

What then are the observed properties of circumstellar matter in HBe stars? Is there evidence for grain growth and processing in HBe stars, similar to that seen in H Ae stars? Is the spectral energy distribution of HBe stars at IR wavelengths different from that of lower mass stars, and how does this translate into (inner) disk geometry? To answer these questions and put HBe stars into perspective, observations at mid-IR wavelengths are needed at high angular resolution. So far, many studies were based on IR data obtained with large beams, which caused contamination with ambient molecular cloud emission, which is prominent for massive stars because of their strong ultraviolet (UV) radiation field. In the present study, we employ the subarcsecond spatial resolution in imaging and spectroscopy that VISIR at the VLT offers to study the immediate environment of HBe stars on spatial scales comparable to the disks they may have.

This paper is organized as follows: in Sect. 2 we discuss the selection of our sample of HBe stars and their basic properties. Sections 3 and 4 describe the observations and data reduction procedures, and we analyze the images and spectra in Sects. 5 and 6. In Sect. 7 we discuss the results and compare the HBe stars to their lower mass H Ae counterparts. Section 8 contains the main conclusions.

2. Sample

2.1. Selection

We have taken targets from the Herbig Ae/Be catalogs of Thé et al. (1994) and Vieira et al. (2003) and supplemented this list with Herbig Ae/Be stars discovered by Perez et al. (1989), de Winter et al. (1997), and van den Ancker et al. (1998). We selected the targets based on several criteria. They have a spectral type B or O, with an uncertainty in spectral type of less than three subclasses. They are known to have an IR excess from near-IR photometry. They are associated with a star-formation region. They are bright enough to observe with VISIR in the mid-IR according to their IRAS $12 \mu\text{m}$ flux or according to the flux expected from an extrapolation of the photospheric flux at optical wavelengths. They are observable with the VLT in Chile and consequently mostly located in the southern hemisphere. While our approach is optimized to select young massive stars, it is possible that our sample is contaminated with stars in other evolutionary stages. We address this problem in Sect. 7.4. Furthermore, recent improvements of the spectral types have shifted two of the targets to the H Ae class (LkH α 208 and LkH α 339). These were kept in the sample for the sake of comparison and completeness.

2.2. SEDs

To establish the pre-main-sequence nature of our targets, we pinpointed their position in the Hertzsprung-Russell (HR) diagram. To do this we gathered all available photometry and constructed spectral energy distributions (SEDs) for all targets that were successfully observed with the VISIR spectrograph (see Fig. 1). We gathered spectral types, effective temperatures, and distances from the literature (see Table 1). If the effective temperature was not stated by the authors, we used de Jager & Nieuwenhuijzen (1987) to find a value corresponding to the spectral type. With the effective temperature and distance we were able to assign a theoretical stellar SED using the models from Kurucz (1991). By comparing this with the observed photometry, we obtained the optical extinction, A_V , and the luminosity of the star L_* . In this comparison, we used the Steenman & The (1991) interstellar extinction law characterized by a total to selective extinction $R_V = 3.1$. For three targets no distance estimates are specified in the literature. For these we used the spectroscopic parallax to determine the stellar luminosity. For Hen 3-847 we used $\log g = 3.84$ (see van den Ancker et al. 1998 and references therein), for PDS 477 and PDS 543 we derived $\log g = 4.0$.

In Fig. 1 we plot the constructed SEDs. Square symbols denote the de-reddened photometry. Curves are the Kurucz models. The plots show that the stellar photosphere of a number of sources is not properly constrained, which increases the uncertainty on the luminosity somewhat, especially when the uncertainty on the spectral type is large as well (e.g. PDS 204). For the other targets the goodness of fit of the Kurucz model to the de-reddened photometry give confidence in the reliability of the derived luminosities.

2.3. Stellar parameters

In Table 1 we summarize the stellar parameters for our sample targets. We only derived optical extinctions and luminosities for the targets that were successfully observed with the VISIR spectrograph. Masses for the stars below $7 M_{\odot}$ were found by interpolating in the HR diagram (see Fig. 2) between PMS evolution

Table 1. The stellar parameters of our sample of Herbig Be stars.

#	Name	Other	Right Ascension	Declination	Spec. Type	Ref.	$\log T_{\text{eff}}$ [K]	Distance [kpc]	Ref.	A_V	$\log L_*$ [$L_\odot$]	Radius [$R_\odot$]	Mass [$M_\odot$]	Group
1	PDS 204	MWC 778	05 50 13.5	+23 52 17	B1?e	V03	4.41 $\pm$ 0.14	1.0 $\pm$ 0.3	H08	4.5 $\pm$ 0.4	3.67 $\pm$ 0.15	3.5 $\pm$ 0.7	10 $\pm$ 2	U
2	MWC 789	HD 250550	06 01 59.99	+16 30 56.7	B9e	H04	4.04 $\pm$ 0.03	0.7	F84	0.4 $\pm$ 0.1	2.14 $\pm$ 0.25	3.3 $\pm$ 0.5	3.1 $\pm$ 0.6	II
3	LkH α 208	HBC 193	06 07 49.46	+18 39 26.3	A7e	H04	3.91 $\pm$ 0.03	1.0	H92	0.9 $\pm$ 0.1	1.61 $\pm$ 0.11	3.2 $\pm$ 0.5	2.4 $\pm$ 0.4	U
4	LkH α 339	HBC 197	06 10 57.8	-06 14 37	A1e	H04	3.97 $\pm$ 0.05	0.83 $\pm$ 0.05	H76	2.4 $\pm$ 0.1	1.36 $\pm$ 0.03	1.8 $\pm$ 0.1	2.1 $\pm$ 0.4	U
5	MWC 137	PK 195-00.1	06 18 45.50	+15 16 52.4	B0e	H92	4.49 $\pm$ 0.05	1.3	H92	4.5 $\pm$ 0.1	4.42 $\pm$ 0.11	5.7 $\pm$ 0.8	16 $\pm$ 1	II
6	LkH α 215	V699 Mon	06 32 41.80	+10 09 33.6	B6e	H04	4.14 $\pm$ 0.08	0.8	H82	2.0 $\pm$ 0.1	2.79 $\pm$ 0.10	4.3 $\pm$ 0.6	4.7 $\pm$ 0.9	G
7	MWC 147	HD 259431	06 33 05.19	+10 19 20.0	B1Ve	V98	4.41 $\pm$ 0.05	0.8	H82	1.6 $\pm$ 0.1	3.94 $\pm$ 0.11	4.8 $\pm$ 0.7	6.6 $\pm$ 1.3	U
8	R Mon	BD +08 1427	06 39 09.95	+08 44 10.7	B8IIIev	M01	4.07 $\pm$ 0.05	0.8	J82	2.5 $\pm$ 0.1	2.12 $\pm$ 0.12	2.8 $\pm$ 0.4	3.4 $\pm$ 0.8	II
9	PDS 241 [#]	Ced 92	07 08 38.8	-04 19 08	B0e	V03	4.48 $\pm$ 0.05	7.2	W89	2.9 $\pm$ 0.1	5.18 $\pm$ 0.11	14 $\pm$ 2	32 $\pm$ 6	G
10	PDS 27	DW CMa	07 19 35.94	-17 39 18.7	B2?e	V03	4.34 $\pm$ 0.14	1.25	V03	4.8 $\pm$ 0.1	3.80 $\pm$ 0.11	5.5 $\pm$ 0.8	9.1 $\pm$ 1.8	II
11	Hilt 641 [†]	HD 64315	07 52 20.28	-26 25 46.7	O6Vne	W82	4.60 $\pm$ 0.03	6.4	G06	-	-	-	-	-
12	Hen 3-331	HD 85567	09 50 28.54	-60 58 03.0	B2ne	M101	4.32 $\pm$ 0.08	1.5 $\pm$ 0.5	M101	1.1 $\pm$ 0.1	4.17 $\pm$ 0.16	9 $\pm$ 2	12 $\pm$ 2	II
13	Hen 3-847	CPD-48 5215	13 01 17.80	-48 53 18.8	B5e	V03	4.18 $\pm$ 0.03	1.66 $\pm$ 0.23	V11	0.8 $\pm$ 0.1	3.22 $\pm$ 0.08	5.9 $\pm$ 0.6	6.2 $\pm$ 1.2	II
14	Hen 3-1110	HD 141926	15 54 21.83	-55 19 44.8	B2IIIne	V03	4.31 $\pm$ 0.05	0.65	V03	2.4 $\pm$ 0.1	3.88 $\pm$ 0.11	7.0 $\pm$ 1.0	14 $\pm$ 2	G
15	MCW 1264 [#]	HD 152291	16 54 24.16	-40 39 09.5	B2II:e	T94	4.26	-	-	-	-	-	-	-
16	V921 Sco	CD-42 11721	16 59 06.78	-42 42 08.4	B0?pe	S90	4.45 $\pm$ 0.04	1.15 $\pm$ 0.15	B07	5.0 $\pm$ 0.1	4.83 $\pm$ 0.07	11 $\pm$ 1	21 $\pm$ 4	II
17	MWC 878	CPD-38 6814	17 24 44.69	-38 43 51.5	O9/B0e	M101	4.48 $\pm$ 0.05	3.3 $\pm$ 0.4	M101	2.4 $\pm$ 0.1	4.77 $\pm$ 0.07	8.9 $\pm$ 0.8	20 $\pm$ 4	II
18	Hen 3-1418 [#]	HD 319896	17 31 05.85	-35 08 29.3	B4e	V03	4.23 $\pm$ 0.04	1.4 $\pm$ 0.3	V03	-	-	-	-	-
19	Hen 3-1444 ^o	HD 320156	17 37 58.50	-35 23 04.3	B0e	N95	4.48	-	-	-	-	-	-	-
20	PDS 152 [#]	HD 316051	17 39 52.18	-27 23 44.1	B5e	N95	4.18	-	-	-	-	-	-	-
21	MWC 593 [#]	CPD-24 5962	17 49 10.17	-24 14 21.3	B0Ia:e	V93	4.41	-	-	-	-	-	-	-
22	PDS 477	-	18 00 30.10	-16 47 22.7	B1e	V03	4.48 $\pm$ 0.06	6.7 $\pm$ 0.7	V11	4.4 $\pm$ 0.1	4.73 $\pm$ 0.08	8.5 $\pm$ 0.8	19 $\pm$ 4	II
23	AS 267 [†]	Hen 3-1559	18 01 56.65	-23 41 31.2	B5IV:ne	T94	4.21	-	-	-	-	-	-	-
24	NGC 6530-45 [†]	V5098 Sgr	18 02 50.21	-24 16 19.2	B5e	V97	4.18	1.8 $\pm$ 0.1	S90	-	-	-	-	-
25	LkH α 112 [†]	NGC 6530-180	18 04 22.74	-24 22 09.8	B2Ve	V97	4.32	1.8 $\pm$ 0.1	S90	-	-	-	-	-
26	LkH α 115 [#]	NGC 6530-245	18 04 50.63	-24 25 41.9	B2Ve	A07	4.32	1.8 $\pm$ 0.1	S90	-	-	-	-	-
27	LkH α 260	NGC 6611-494	18 19 09.39	-13 50 41.1	B6e	DW97	4.15 $\pm$ 0.04	2.14 $\pm$ 0.1	B99	3.2 $\pm$ 0.1	2.65 $\pm$ 0.03	3.5 $\pm$ 0.1	4.4 $\pm$ 0.8	U
28	MWC 297	NZ Ser	18 27 39.60	-03 49 52.0	B1.5Ve	D97	4.36 $\pm$ 0.03	0.25 $\pm$ 0.03	D97	7.7 $\pm$ 0.1	3.92 $\pm$ 0.06	5.8 $\pm$ 0.4	10.1 $\pm$ 2	II
29	AS 310	PK 026+01.1	18 33 21.17	-04 58 06.7	B1e	H04	4.40 $\pm$ 0.07	2.5	B93	3.7 $\pm$ 0.1	4.23 $\pm$ 0.10	6.8 $\pm$ 1.0	12 $\pm$ 2	U
30	PDS 543	-	18 48 00.66	+02 54 17.1	B1e	V03	4.48 $\pm$ 0.06	2.8 $\pm$ 0.3	V11	4.4 $\pm$ 0.1	4.73 $\pm$ 0.08	8.5 $\pm$ 0.8	19 $\pm$ 4	U

Notes. Of a total of 30 targets, 19 were covered spectroscopically, 4 were not detected in the VISIR imaging mode ^(†), 6 were too faint for spectroscopic follow-up ^(#) and 1 target was not spectroscopically covered due to a lack of observation time ^(o). The astrometry was taken from Simbad. The spectral types and distances were taken from the literature, with the references indicated in Cols. 7 and 10. The optical extinction, luminosity and radius followed from our analysis of the optical photometry. The masses were determined by comparing T_{eff} and L_* with PMS evolution tracks of [Siess et al. \(2000\)](#) and ZAMS positions of [Meynet et al. \(1994\)](#). The group classification is based on the IR SED, as explained in Sect. 7.1. Note that LkH α 208 and LkH α 339 are A stars. They entered the sample because of a previous misclassification and we kept them in the sample to facilitate the comparison of HBe with H Ae stars.

References. (A07) [Arias et al. 2007](#); (B99) [Belikov et al. \(1999\)](#); (B07) [Borges Fernandes et al. \(2007\)](#); (B93) [Brooke et al. \(1993\)](#); (DW97) [de Winter et al. \(1997\)](#); (D97) [Drew et al. \(1997\)](#); (F84) [Finkenzeller & Mundt \(1984\)](#); (G06) [Gamen et al. \(2006\)](#); (H08) [Herbig & Vacca \(2008\)](#); (H82) [Herbst et al. \(1982\)](#); (H76) [Herbst & Racine \(1976\)](#); (H04) [Hernández et al. \(2004\)](#); (H92) [Hillenbrand et al. \(1992\)](#); (J82) [Jones & Herbig \(1982\)](#); (M101) [Miroshnichenko et al. \(2001\)](#); (M01) [Mora et al. \(2001\)](#); (N95) [Nesterov et al. \(1995\)](#); (S90) [Shore et al. \(1990\)](#); (T94) [Thé et al. \(1994\)](#); (V97) [van den Ancker et al. \(1997\)](#); (V98) [van den Ancker et al. \(1998\)](#); (V03) [Vieira et al. \(2003\)](#); (V11) this paper; (V93) [Vijapurkar & Drilling \(1993\)](#); (W82) [Walborn \(1982\)](#); (W89) [Wouterloot & Brand \(1989\)](#).

Fig. 1. Extinction-corrected spectral energy distributions of the sample stars that were observed with the VISIR spectrograph. Overplotted are Kurucz models (black lines). VISIR photometry in the SiC filter (see Tables 3 and 6) is indicated with red triangles and the group classification is indicated in the upper right corners (see Sect. 7.1).

References. Wesseliuss et al. (1982) (ANS UV); de Geus et al. (1990) (Walraven WULBV); de Winter et al. (2001) (WULBV, Johnson/Cousins UBVR, Near-IR); Herbst & Shevchenko (1999) (UBVR); Kilkenny et al. (1985) (UBVR and JHKLM); Hillenbrand et al. (1992) (UBVR and JHKLM); Gail (2004) (UBVR); Weaver & Jones (1992) (IRAS add-scans); 2MASS, IRAS and MSX catalogs.

tracks of Siess et al. (2000). For the stars above $7 M_{\odot}$ we interpolated between MS evolution tracks of Meynet et al. (1994). We adopted 20% errors on the masses. The high-mass Herbig stars

($M \geq 8 M_{\odot}$) are known to become visible only when they reach the ZAMS (Palla & Stahler 1993). Therefore we would expect a lot of young stars close to the ZAMS. However, the optical

Fig. 2. HR diagram of our spectroscopic sample. Overplotted are the Siess et al. (2000) PMS evolution tracks (solid lines) and the Meynet et al. (1994) ZAMS (dotted line). The stars are identified with the number from the first column of Table 1.

Table 2. A comparison with stellar parameters from the literature and luminosities as derived with the assumption that $R_V = 5$.

Name	A_V	Literature		Ref.	$R_V = 5$	$R_V = 3.1$
		$\log L_*$ [$L_\odot$]	Mass [$M_\odot$]		$\log L_*$ [$L_\odot$]	$\log L_*$ [$L_\odot$]
PDS 204	3.0	3.06	–	H08	4.76	3.67
MWC 789	0.7	2.31	3.9	H04	2.23	2.14
LkH α 208	1.2	1.78	2.4	H04	1.79	1.61
LkH α 339	4.3	2.08	3.4	H04	1.80	1.36
MWC 137	4.5	4.46	18.9	H92	5.35	4.42
LkH α 215	3.2	3.24	6.6	H04	3.16	2.79
MWC 147	2.0	3.50	9.7	H04	3.41	3.26
R Mon	4.3	3.55	10.4	H92	2.71	2.12
Hen 3-331	1.0	3.7	9	Mi01	4.40	4.17
V921 Sco	4.8	4.0	9	B07	5.90	4.83
MWC 878	–	5.3	30	Mi01	5.30	4.77
LkH α 260	2.3	2.57	–	DW97	3.30	2.65
MWC 297	7.7	4.05	10	D97	5.71	3.92
AS 310	6.6	5.43	43.5	H04	5.00	4.23

Notes. The last column repeats our derived values with $R_V = 3.1$ to accommodate the comparison. The table gives an assessment of typical conservative uncertainties on the stellar parameters. The reference abbreviations are identical to those defined in the footnote of Table 1.

selection of the targets has a bias toward low A_V and consequently it favors stars that have dispersed their natal clouds. These likely are young main-sequence stars.

To calculate the uncertainties on the luminosities and radii (see Table 1), we did not take the uncertainties on the effective temperatures into account, but accounted for the uncertainties in the distances only. Most of the distances are based on associations with star-formation regions and clusters and their uncertainties assume the associations are correct. When no error on the distance was stated in the literature, we assumed an error of 20%. Another source of uncertainty that was not taken into account is in the choice of R_V . Some studies (e.g. Hernández et al. 2004) argue that $R_V = 5.0$ is more appropriate for star-forming regions. Such a higher R_V value leads to considerably higher luminosities. In Table 2 we provide values available in the literature and compare these to values that were derived with

Table 3. VISIR filters that were used to image our targets.

Filter	λ_c [μm]	Width [μm]	$\ln(R)$ [counts/s/Jy]	$\langle A \rangle$
PAH2	11.25	0.59	12.8 ± 0.2	0.22 ± 0.02
PAH2_2	11.88	0.37	12.4 ± 0.2	0.22 ± 0.03
SiC	11.85	2.34	11.8 ± 0.3	0.30 ± 0.04

Notes. The fourth and fifth columns give the natural logarithm of the responsivity (R) and the corresponding mean extinction per unit airmass ($\langle A \rangle$) as derived in Sect. 5.1.

$R_V = 5.0$ and $R_V = 3.1$. The variation in the luminosities in Table 2 illustrates the remaining uncertainties.

3. Observations

3.1. Imaging

From October 2006 to May 2007 N -band imaging was obtained with the VLT Imager and Spectrometer for mid Infrared (VISIR, see Lagage et al. 2004). The targets were observed for typically ~ 3 min. in the small-field mode (pixel field of view = $0.075''$) and in each of the three filters: SiC, PAH2, and PAH2_2. These focus on the $10\mu\text{m}$ silicate feature, the $11.2\mu\text{m}$ PAH feature, and the continuum redward of the PAH feature respectively (see Table 3). For the science targets we employed parallel chopping and nodding to remove the atmospheric background. A maximum chopper throw of $30''$ was chosen to avoid any confusion with surrounding nebulosity. Originally we chose chopping rotations, which were offset from the standard north-south orientation for the same reason of avoiding confusion, because this was expected from optical and IRAS imaging of the targets. In the next observing period we did use the standard north-south orientation, because almost all targets turned out to be nearly point-like in the mid-IR. Observations were carried out in ESO's service mode at airmass < 1.6 and optical seeing $< 1.2''$, corresponding to a seeing in the N -band of $\leq 0.5''$. Photometric standard stars were observed in all filters less than three hours before or after the science targets. Table 4 contains a detailed log of the observations. It lists the target names, the imaging filters, the image orientation, the chopper throw, the date and time, the airmass and optical seeing, the integration time and the target category (calibration or science). Four sources were not detected with our VISIR imaging. They have been indicated with a $\dagger$ symbol in Table 1.

3.2. Spectroscopy

VISIR long-slit low-resolution ($R \approx 300$) spectra were also obtained in ESO's service mode from January 2007 to February 2008. The complete N -band was mapped with the sequence of four separate observations in the 8.5, 9.8, 11.4, and $12.2\mu\text{m}$ settings. Each observation had a typical integration time of ~ 5 min, a slit-width of $0.4''$, a north-south orientation and a chopping throw of $8''$. Based on our imaging results, some observations were performed using different choices of slit orientation and chop throw. In addition to the four sources that were not detected in imaging at all (indicated with $\dagger$ in Table 1), six sources turned out to be too faint for spectroscopic follow up ($\#$) and one was not covered owing to lack of observation time (Hen 3-1444). Several sources displayed apparent extended emission; for these the slit was rotated to select the major axis of the target. For AS 310 and PDS 204 wider chopper throws were chosen because of their larger mid-IR sizes. Bright spectroscopic standard stars

Fig. 3. VISIR imaging in the PAH2 filter of those targets that display a compact emission. The field of view is 16.8'' by 16.8''. The black lines indicate the slit orientation of the spectroscopic observations. In the bottom right we indicate the image orientation when it deviates from the default, i.e. north up and east to the left.

were observed directly before and after the science observation for the purpose of telluric correction, but also to determine the spectroscopic point spread function (PSF). Table 5 contains a detailed log of the observations. The table lists the target names, the wavelength settings, the orientation of the slit, the chopper throw, the date and time, the airmass and optical seeing, the integration time and the target category (calibration or science).

4. Data reduction

4.1. Image reduction

The raw VISIR images and spectra were reduced with a dedicated pipeline that we developed (see [Pantín 2010](#)). The basics are explained in our study of H Ae stars (see [Verhoeff 2009](#)). The resulting images are displayed in Fig. 3 for the PAH2 filter. For some targets with detached emission patches we display both the PAH2 filter (Fig. 4) and the PAH2_2 filter (Fig. 5). The images are displayed on a logarithmic scale and the color contrast ranges from 1σ of the background (white) to 0.9 of the peak flux (black). When the orientation deviates from the standard north up and east left, a compass in the bottom right of the images is supplied. For the observations that were followed-up with spectroscopy, the slit orientation is indicated.

4.2. Telluric correction

The VISIR spectra of our targets were calibrated immediately before and after the science observation, which in most cases allowed us to do the telluric correction with an airmass interpolation of the extinction. The principle is explained in detail in

[van Boekel et al. \(2004\)](#) and it was applied for VISIR spectra of H Ae stars in [Verhoeff \(2009\)](#). In some cases there was only one suitable calibration measurement. For those cases we followed the formalism described in [Verhoeff \(2009\)](#). The flux calibration was achieved with the photometry from the SiC filter (see Sect. 5.1). The resulting spectra of our HBe stars are plotted in Fig. 6. For comparison we overplotted ISO spectra from the ISO archive and *Spitzer* spectra taken from [Acke et al. \(2010\)](#) and Van den Ancker (unpublished; *Spitzer* PID 50180).

4.3. FWHM extraction

Because VISIR employs a long slit, spatial information of the targets is maintained along the slit. To characterize this information, we fitted Gaussians to the spatial direction of the 2D spectra to extract the spatial FWHM in all wavelength bins. The resulting plots can be found in Fig. 7. The combined measurement error and fitting error was estimated by evaluating the standard deviation of the residuals after subtraction of a spline fit. The point spread function (PSF) of the combined system of VISIR and the VLT has been proven to be quite unstable (see e.g. [Pantín 2010](#)). To determine the PSF during science measurements we constructed a “statistical calibrator” from a sample of ~ 130 calibration measurements. A detailed description of our analysis can be found in [Verhoeff \(2009\)](#), below we provide a brief summary.

We identified three components that contribute to the PSF: the diffraction limit, the atmospheric seeing, and a stochastic telescopic broadening. To establish a reliable PSF and its uncertainty we determined the dependence on the atmospheric optical seeing and the magnitude of the random distribution. This was achieved by plotting all calibration measurements in a diagram

Fig. 4. VISIR imaging in the PAH2 filter of the targets that display detached emission patches from the molecular cloud environment. The field of view is 19.2'' by 19.2''. The black lines indicate the slit orientation of the spectroscopic observations. In the bottom right we indicate the image orientation when it deviates from the default, i.e. north up and east to the left.

Fig. 5. Same as Fig. 4, but in the PAH2_2 filter.

with their IR FWHM size against their optical seeing, after a correction for their airmass. The fit of these data defines our statistical calibrator and the scatter around it gives the uncertainty. In practice a PSF and its uncertainty can now be found for a random measurement by supplying an airmass-corrected optical seeing value, reading the corresponding IR FWHM size from the fit, and transforming that value back to the airmass of the measurement. In our analysis we will also use the calibrator nearest in time as a reference.

5. Analysis of the images

5.1. Photometry

Most of our sources are surrounded by nebulosity, which contributes significantly to the IRAS flux. Imaging with VISIR allows one to zoom in to an area of $\sim 1''$ around the star. The flux levels that are obtained in this way give new information about the star and disk.

From inspection of the morphology of the stars in the obtained imaging we conclude that a standard circular photometry aperture is suitable for all sources. More specific, we measured the source counts within a circle of radius $r = 13$ pixels ($\sim 1.0''$) and the background within an annulus within radii $r = 18$ to $r = 23$ pixels ($\sim 1.4''$ to $\sim 1.7''$). For a typical PSF the source aperture encompasses the first and second airy rings, the third airy ring is ignored and the background aperture runs from the fourth to the fifth airy ring.

The apertures were applied to obtain the background-subtracted flux levels in counts per second of all science and calibration measurements. To obtain the tellurically corrected flux levels of our science targets we used

$$I = S \frac{1}{R} e^{A \cdot m}, \quad (1)$$

where I is the intrinsic flux, S the measured background-subtracted flux, m the airmass of the measurement and R and A the responsivity of the system and the atmospheric extinction per unit airmass. To find the responsivity of the system, we looked at the ensemble of all calibrators of all nights and plotted the natural logarithm of their observed counts over their model fluxes against the corresponding airmass values. In this way a least-squares linear fit to the data points allows us to obtain the responsivity:

$$\ln\left(\frac{S}{I}\right) = \ln(R) - A \cdot m. \quad (2)$$

The intersection with the y-axis represents the responsivity and the slope is determined by the extinction per unit airmass. The latter is not a constant, it depends on the humidity and temperature of the atmosphere. Nevertheless, when we fit the ensemble of calibrators, the uncertainty of the responsivity becomes small compared to the other errors.

Now that we know the value of the responsivity, we can calculate a value of the extinction per unit airmass for every single calibration measurement through an inversion of Eq. (1). To obtain the extinction per unit airmass at the time of the science measurement, we used the calibrator nearest in time. To estimate the accompanying error, we used the variation in extinction as derived from all calibrators during the same night.

This procedure was followed for all three filters (see Table 3) and all science targets; the results are summarized in Table 6. The listed errors are obtained by differential propagation of the measurement errors and the errors in the responsivity and extinction. For the undetected sources Hilt 641, AS 267, NGC 6530-45, and LkHa 112, we assert an upper limit in the SiC filter of 0.1 Jy.

5.2. Spatial emission profile

We analyzed the spatial emission profile of the images by extracting horizontal cuts through the source maxima. In the vertical direction the profiles are corrupted by detector ghosts, caused by the fairly high brightness of some sources (see Pantin 2010).

Table 6. Flux levels of our VISIR imaging of the targets.

Target	PAH2 [Jy]	PAH2_2 [Jy]	SiC [Jy]	F_{12} [Jy]	Neb	$\log L_{12}/L_*$
PDS 204	4.2 ± 0.8	3.5 ± 0.7	3.7 ± 0.9	6.4 ± 0.3	✓	-7.5 ± 0.09
MWC 789	4.5 ± 0.7	3.8 ± 0.6	4.6 ± 0.7	4.5 ± 0.3	✓	-6.2 ± 0.06
LkH α 208	3.8 ± 0.6	3.0 ± 0.4	3.2 ± 0.5	3.4 ± 0.03	✓	-5.5 ± 0.06
LkH α 339	1.1 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	6.6 ± 0.1	✓	-6.0 ± 0.05
MWC 137	3.2 ± 0.5	3.0 ± 0.4	3.1 ± 0.5	20.4 ± 1.0	✓	-8.1 ± 0.06
LkH α 215	0.8 ± 0.1	0.64 ± 0.06	0.7 ± 0.1	9.1 ± 0.5	✓	-7.6 ± 0.06
MWC 147	6.9 ± 0.1	5.8 ± 0.6	6.2 ± 0.6	12.8 ± 1.3	✓	-7.7 ± 0.04
R Mon	41 ± 4	41 ± 4	43 ± 4	56.7 ± 0.1	✓	-5.1 ± 0.04
PDS 241	0.12 ± 0.05	0.04 ± 0.02	0.08 ± 0.03	14.1 ± 1.6	✓	-9.0 ± 0.14
PDS 27	14 ± 1	13.9 ± 1.4	15 ± 1	15.0 ± 0.6	–	-6.8 ± 0.03
Hen 3-331	6.5 ± 1	5.8 ± 0.6	5.5 ± 0.8	6.4 ± 0.2	–	-7.5 ± 0.06
Hen 3-847	34 ± 4	29 ± 2	30 ± 4	36.1 ± 1.4	–	-5.7 ± 0.05
Hen 3-1110	0.30 ± 0.05	0.29 ± 0.04	0.31 ± 0.06	0.76 ± 0.1	–	-9.2 ± 0.08
MCW 1264	0.07 ± 0.05	0.05 ± 0.04	0.08 ± 0.06	13.3 ± 4.2	–	–
V921 Sco	35 ± 7	29 ± 4	34 ± 6	124.2 ± 7.5	✓	-7.6 ± 0.07
MWC 878	23 ± 5	20 ± 3	21 ± 4	21.1 ± 1.3	–	-6.8 ± 0.08
Hen 3-1418	0.04 ± 0.02	0.03 ± 0.02	0.07 ± 0.02	2.5 ± 0.2	–	–
Hen 3-1444	6.2 ± 1.2	5.7 ± 0.8	5.5 ± 1.1	6.7 ± 0.4	–	–
PDS 152	0.13 ± 0.05	0.18 ± 0.04	0.12 ± 0.04	3.7 ± 0.4	–	–
MWC 593	0.10 ± 0.03	0.10 ± 0.03	0.09 ± 0.03	<1.6	–	–
PDS 477	2.3 ± 0.3	2.1 ± 0.3	2.2 ± 0.3	2.8 ± 0.25	–	-7.1 ± 0.06
LkH α 115	0.4 ± 0.1	0.29 ± 0.04	0.28 ± 0.06	–	✓	–
LkH α 260	0.6 ± 0.1	0.44 ± 0.07	0.48 ± 0.07	1.0 ± 0.9	✓	-6.7 ± 0.06
MWC 297	121 ± 18	113 ± 17	123 ± 18	159 ± 6.3	✓	-7.4 ± 0.06
AS 310	1.4 ± 0.6	1.1 ± 0.5	1.2 ± 0.5	51.5 ± 0.2	✓	-7.8 ± 0.15
PDS 543	2.3 ± 0.5	1.9 ± 0.3	2.0 ± 0.4	4.2 ± 0.2	–	-7.9 ± 0.08

Notes. The F_{12} column represents the 12 μ m IRAS measurement (MSX C for LkH α 260). The column underneath “Neb” indicates whether an optical reflection nebula is present in the Digitized Sky Survey at 0.65 μ m. In the last column we derived the 12 μ m excess fraction of the circumstellar disks. For Hilt 641, AS 267, NGC 6530-45, and LkH α 112 we supply an upper limit of 0.1 Jy in the SiC filter.

Table 7. Quadratically subtracted FWHM sizes of the targets in all imaging filters.

Target	PAH2		PAH2_2		SiC		Width at low I	Plateau?
	[$''$]	[AU]	[$''$]	[AU]	[$''$]	[AU]		
PDS 204	<0.50	<500	<0.33	<330	<0.43	<430	Cloud	✓
MWC 789	<0.43	<300	<0.38	<260	<0.42	<300	Point	✓
LkH α 208	<0.53	<530	<0.40	<400	<0.53	<530	Extended?	✓
LkH α 339	<0.41	<340	<0.41	<340	<0.40	<330	Point	✓
MWC 137	$0.33^{+0.06}_{-0.09}$	430	<0.51	<660	$0.36^{+0.06}_{-0.07}$	470	Extended?	✓
LkH α 215	<0.59	<470	<0.50	<400	<0.62	<500	Point	✓
MWC 147	<0.61	<490	<0.55	<440	<0.47	<380	Cloud	✓
R Mon	<0.53	<420	<0.53	<430	<0.64	<510	Point	✓
PDS 241	$0.58^{+0.03}_{-0.03}$	4180	<0.08	<560	$0.59^{+0.03}_{-0.03}$	4210	Cloud	✓
PDS 27	<0.43	<540	<0.39	<490	<0.42	<530	Extended?	✓
Hen 3-331	<0.51	<770	<0.40	<600	<0.48	<720	Extended?	✓
Hen 3-847	<0.48	<800	<0.46	<760	<0.50	<830	Point	✓
Hen 3-1110	$0.32^{+0.05}_{-0.07}$	210	<0.39	<250	<0.33	<210	Extended	✓
V921 Sco	<0.44	<510	<0.41	<480	<0.44	<500	Extended	✓
MWC 878	<0.49	<1620	<0.38	<1250	<0.44	<1450	Point	✓
Hen 3-1444	<0.49	–	<0.37	–	<0.50	–	Point	✓
PDS 152	<0.52	–	<0.45	–	<0.52	–	Extended	✓
MWC 593	<0.42	–	<0.37	–	<0.29	–	Extended	–
PDS 477	<0.32	<2110	<0.47	<3150	<0.49	<3260	Extended?	✓
LkH α 115	<0.31	<560	<0.24	<430	<0.24	<440	Extended	–
LkH α 260	<0.52	<1100	<0.42	<910	<0.53	<1130	Extended	✓
MWC 297	<0.36	<90	$0.45^{+0.06}_{-0.05}$	110	$0.26^{+0.05}_{-0.07}$	70	Extended?	✓
AS 310	$1.25^{+0.05}_{-0.05}$	3140	$1.32^{+0.05}_{-0.05}$	3310	$1.28^{+0.03}_{-0.03}$	3200	Cloud	✓
PDS 543	<0.31	<870	<0.25	<700	<0.39	<1090	Extended?	✓

Notes. For the targets that were not significantly resolved, we report the 3σ upper limit. The corresponding sizes in AU were obtained with the distances of Table 1. In the last but one column we give a description of the spatial emission profile as observed at lower intensities in the PAH2 filter. The last column indicates whether a plateau emission is present, based on the background pattern in the PAH images.

Fig. 6. VISIR N -band spectra of our targets. Overplotted are *Spitzer* spectra (thick green), ISO spectra (thick orange), and a TIMMI2 spectrum (blue) where available. These spectra were scaled to the VISIR spectrum with the factor (f) indicated in the bottom right for the *Spitzer* and ISO spectra. Indicated in the top right are quality parameters, when they reach levels of concern. If the airmass (m) exceeded 1.5, the value is indicated. When the sensitivity value (S) was greater than five times the median value of the performance history of VISIR (i.e. poor performance), S is indicated in units of this median sensitivity value.

Given the high amplitude of the chopping throw (30'') and the observational mode used (parallel nodding mode), the limited accuracy of superimposition of the two central beams results in a potential degradation of the spatial resolution. The chopped-only images were therefore analyzed separately. The two profiles corresponding to the two nod positions are shown in Fig. 8. These profiles were averaged over three pixel rows centered on the peak intensity of the sources. Overplotted in green are the calibration measurements that were observed within two hours before or after the science target and had minimum airmass differences. The average of these two measurements is a reliable

representation of the PSF. The difference between the profiles of the different nodding positions provides an indication of the reliability of the measurements. For the sources with low signal-to-noise ratio (S/N), such as PDS 241, we were forced to use a total stack of the data, which thus results in a single profile curve. Hen 3-1418 and MCW 1264 were too faint for a meaningful analysis.

To obtain a size measurement of our targets, we fitted the extracted emission profiles with a Gaussian. Where we had multiple profiles, we averaged the resulting FWHM values. The nearest calibration image was then taken as the PSF and was

Fig. 7. Size of all our targets as a function of wavelength (black lines). Plotted in green are calibration measurements taken immediately before or after the science exposures. Plotted in blue is the statistical calibrator as determined from the entire sample of calibrators. The red line is the theoretical diffraction limit.

Fig. 7. continued.

quadratically subtracted from the science measurement. The error in the PSF (σ_{PSF}) was estimated by taking the standard deviation of all calibration measurements in the same filter of the program. The measurement errors were estimated to be $0.3 \cdot \sigma_{\text{PSF}}$. For high seeing conditions we increased this error continuously with $1.0 \cdot \sigma_{\text{PSF}}/\text{arcsec}$ over an optical seeing of $0.7''$. The final errors were obtained by numerical propagation of the measurement and PSF errors. This rather conservative error budgeting was chosen because the imaging was meant to provide a quick grasp on morphology and photometry and the PSF was therefore relatively underdetermined. The analysis was performed for every target and every filter. The results are displayed in Table 7.

The last two columns of Table 7 give a description of the spatial emission profile at low intensities. After inspection of the images we selected targets that contain detached emission components, indicated with the label “cloud”. We display these separately in Fig. 4. We assume that these components are caused by illuminated natal cloud remnants. These sources also show associated optical nebulosity in the Digitized Sky Survey $0.65 \mu\text{m}$ imaging (see “Neb” column in Table 6), which is consistent with this hypothesis. In the continuum filter (PAH2_2) the features are nearly absent (see Fig. 5), indicating that the nature of the emission is most likely fluorescence from PAH molecules. After comparing the emission profiles in Fig. 8 with their calibrators, we were able to discriminate between targets that are “point”-like and those that have spatially extended emission. We assigned the label “extended” when the profiles of both nod positions were at any intensity level more extended than the most extended profile of the calibrator. Note, however, that these qualifications are slightly speculative because of the underdetermined PSF. We stressed this by adding a question mark where there were seeing variations between science and calibration measurements. Finally, we indicate the presence of the diagonally striped pattern in the background of the PAH images (Fig. 3) with a tick-mark. These features appear when observing a fairly extended ($15''$) background, because such a background

causes a telescope residual, which is rotated in two consecutive nod positions (see Pantin 2010). This means that around these targets we can infer the presence of a homogeneous plateau emission on scales larger than $15''$.

6. Analysis of the spectra

6.1. Extinction correction

In order to determine the composition of the circumstellar dust responsible for the $10 \mu\text{m}$ feature, we first need to correct the spectra for interstellar extinction. To convert the optical extinction A_V to an extinction in the N -band, we need to determine the shape of the extinction curve, which is quite different for the diffuse interstellar medium (ISM) and for dense molecular clouds. Chiar et al. (2007) set the maximum A_V for reliable use of the diffuse ISM extinction curve at 12 mag. None of the A_V of the sample stars reach that maximum. We therefore adopted the diffuse ISM extinction law given by Whittet (2003): $A_V = 6.2 \cdot E(J - K_s)$, where $E(J - K_s)$ is the near-IR color excess. A linear fit given by Chiar et al. (2007) of the relation between the optical depth of the $9.7 \mu\text{m}$ silicate absorption feature, $\tau_{9.7}$, and $E(J - K_s)$ provides the conversion to the N -band: $\tau_{9.7} = 0.35 \cdot E(J - K_s) = 0.056 \cdot A_V$. We multiplied the spectra with the function $e^{\tau_{9.7}}$, with $\tau_{9.7}$ given by the ISM silicate feature scaled to the calculated $9.7 \mu\text{m}$ optical depth. The opacity of the ISM dust was taken from Min et al. (2007).

6.2. Compositional fits

In order to allow a direct comparison, the extinction corrected spectra were fitted with the same routine and the same spectral templates as used by van Boekel et al. (2005) for H Ae stars. The reference for amorphous silica was incorrectly stated in that paper (priv. comm.) and should be Henning & Mutschke (1997). The routine fits the most commonly found dust species in

Fig. 8. Spatial emission profiles as observed in the PAH2 imaging. Overplotted are the calibrators nearest in airmass and time (green).

Table 8. Mass fractions of the different components responsible for the 10 μm feature as derived from our compositional fits.

Target	T_c [K]	Olivine		Pyroxene		Forsterite		Enstatite		Am. Silica		8.6	PAH	12.7	Cont.
		Small	Large	Small	Large	Small	Large	Small	Large	Small	Large		11.2		
PDS 204	337 $^{+0}_{-7}$	22 $^{+8.8}_{-7.3}$	47 $^{+10}_{-13}$	—	—	4.7 $^{+0.8}_{-0.7}$	—	—	13 $^{+2.7}_{-2.5}$	—	8.6 $^{+0.9}_{-1.1}$	0.36 $^{+0.05}_{-0.05}$	1.11 $^{+0.11}_{-0.14}$	0.32 $^{+0.14}_{-0.13}$	65.6 $^{+2.5}_{-3.8}$
MWC 789	347 $^{+3}_{-7}$	77 $^{+3.5}_{-5.5}$	—	4.8 $^{+5.4}_{-3.5}$	—	2.5 $^{+0.4}_{-0.4}$	1.7 $^{+0.7}_{-0.8}$	—	8.6 $^{+0.8}_{-1.3}$	—	4.2 $^{+0.7}_{-0.6}$	0.07 $^{+0.03}_{-0.03}$	0.05 $^{+0.06}_{-0.04}$	—	70.2 $^{+2.3}_{-3.3}$
LkH α 208	326 $^{+0}_{-3}$	12 $^{+1.5}_{-1.5}$	—	16 $^{+4.5}_{-4.2}$	54 $^{+4.6}_{-6.2}$	1.2 $^{+0.2}_{-0.2}$	5.7 $^{+0.4}_{-0.4}$	—	—	—	8.9 $^{+0.4}_{-0.4}$	0.17 $^{+0.04}_{-0.04}$	0.07 $^{+0.04}_{-0.04}$	—	24.6 $^{+2.1}_{-2.1}$
LkH α 339	383 $^{+7}_{-3}$	70 $^{+4.5}_{-3.7}$	—	18 $^{+5.1}_{-5.2}$	—	2.4 $^{+0.3}_{-0.4}$	1.5 $^{+1.2}_{-1.1}$	—	3.5 $^{+1.2}_{-1.2}$	—	3.5 $^{+1.3}_{-1.3}$	0.19 $^{+0.12}_{-0.09}$	—	0.21 $^{+0.21}_{-0.14}$	48.8 $^{+1.7}_{-2.4}$
MWC 137	634 $^{+0}_{-8}$	12 $^{+6.9}_{-6.6}$	60 $^{+12}_{-11}$	—	5.9 $^{+8.5}_{-5.1}$	1.2 $^{+0.5}_{-0.5}$	2.8 $^{+2.3}_{-1.9}$	0.6 $^{+0.7}_{-0.5}$	2.5 $^{+2.7}_{-2.1}$	—	11 $^{+0.7}_{-0.8}$	0.13 $^{+0.03}_{-0.03}$	—	0.15 $^{+0.04}_{-0.05}$	83.4 $^{+1.3}_{-1.1}$
MWC 147	466 $^{+1}_{-5}$	—	39 $^{+6.3}_{-4.1}$	2.3 $^{+5.4}_{-2.1}$	39 $^{+4.9}_{-9.8}$	1.4 $^{+0.2}_{-0.2}$	6.8 $^{+0.6}_{-0.7}$	—	—	—	9.3 $^{+0.5}_{-0.5}$	0.03 $^{+0.03}_{-0.03}$	—	0.03 $^{+0.03}_{-0.03}$	56.8 $^{+1.2}_{-0.6}$
R Mon	272 $^{+7}_{-6}$	—	26 $^{+2.5}_{-2.1}$	—	20 $^{+3.5}_{-1.9}$	7.7 $^{+6.5}_{-3.7}$	12 $^{+1.2}_{-1.5}$	19 $^{+1.3}_{-1.5}$	—	8.8 $^{+2.1}_{-1.5}$	—	0.05 $^{+0.05}_{-0.04}$	—	0.13 $^{+0.09}_{-0.07}$	88.5 $^{+2.6}_{-2.4}$
PDS 27	302 $^{+8}_{-8}$	17 $^{+4.4}_{-4.6}$	—	71 $^{+5.5}_{-4.9}$	—	—	0.6 $^{+1.5}_{-0.5}$	—	—	—	10 $^{+2.4}_{-1.6}$	—	—	0.12 $^{+0.05}_{-0.04}$	81.4 $^{+1.8}_{-1.8}$
Hen 3-331	529 $^{+0}_{-7}$	—	73 $^{+3.9}_{-4.7}$	1.7 $^{+4.1}_{-2.6}$	6.9 $^{+5.4}_{-5.4}$	1.4 $^{+0.3}_{-0.3}$	7.4 $^{+0.6}_{-0.6}$	2.9 $^{+0.5}_{-0.5}$	—	0.1 $^{+0.3}_{-0.3}$	5.9 $^{+0.3}_{-0.3}$	0.07 $^{+0.04}_{-0.03}$	0.04 $^{+0.03}_{-0.03}$	0.15 $^{+0.04}_{-0.04}$	73.2 $^{+0.8}_{-1.2}$
Hen 3-847	342 $^{+7}_{-6}$	—	—	14 $^{+2.6}_{-4.2}$	65 $^{+4.1}_{-2.7}$	—	7.3 $^{+0.5}_{-0.5}$	1.5 $^{+0.5}_{-0.4}$	2.5 $^{+0.5}_{-0.6}$	1.2 $^{+0.2}_{-0.3}$	7.5 $^{+0.5}_{-0.5}$	0.18 $^{+0.03}_{-0.03}$	0.15 $^{+0.03}_{-0.04}$	0.16 $^{+0.03}_{-0.03}$	52.4 $^{+1.7}_{-1.7}$
V921 Sco	398 $^{+1}_{-5}$	—	90 $^{+1.3}_{-1.6}$	—	—	—	5.6 $^{+0.9}_{-0.9}$	0.2 $^{+0.4}_{-0.2}$	—	—	3.6 $^{+0.5}_{-0.7}$	0.23 $^{+0.05}_{-0.05}$	—	0.15 $^{+0.05}_{-0.05}$	70.1 $^{+1.1}_{-1.2}$
MWC 878	331 $^{+2}_{-6}$	7.4 $^{+2.9}_{-4.3}$	82 $^{+4.5}_{-3.1}$	—	—	—	4.5 $^{+0.5}_{-0.5}$	—	—	0.3 $^{+0.2}_{-0.2}$	5.7 $^{+0.5}_{-0.4}$	0.07 $^{+0.03}_{-0.03}$	—	0.18 $^{+0.13}_{-0.09}$	66.1 $^{+2.4}_{-1.3}$
PDS 477	326 $^{+7}_{-4}$	30 $^{+1.9}_{-1.9}$	30 $^{+4.5}_{-3.8}$	—	28 $^{+2.5}_{-2.7}$	1.5 $^{+0.2}_{-0.2}$	2.4 $^{+0.5}_{-0.5}$	—	0.9 $^{+0.5}_{-0.5}$	—	5.2 $^{+0.4}_{-0.4}$	0.11 $^{+0.03}_{-0.03}$	0.09 $^{+0.04}_{-0.04}$	0.05 $^{+0.04}_{-0.03}$	54.5 $^{+1.1}_{-1.1}$
LkH α 260	480 $^{+4}_{-9}$	—	—	—	74 $^{+4.3}_{-7.3}$	3.6 $^{+0.5}_{-0.5}$	5.2 $^{+1.3}_{-1.1}$	4.5 $^{+0.9}_{-1.2}$	0.9 $^{+1.4}_{-0.7}$	1.1 $^{+0.5}_{-0.4}$	5.7 $^{+1.1}_{-1.3}$	—	—	—	51.5 $^{+2.6}_{-2.5}$
MWC 297	512 $^{+10}_{-4}$	16 $^{+3.8}_{-4.1}$	70 $^{+4.4}_{-4.5}$	—	—	—	0.6 $^{+0.7}_{-0.5}$	—	0.8 $^{+0.8}_{-0.6}$	—	11 $^{+0.5}_{-0.5}$	0.09 $^{+0.03}_{-0.03}$	0.13 $^{+0.05}_{-0.05}$	0.03 $^{+0.03}_{-0.00}$	83.7 $^{+0.9}_{-1.5}$
AS 310	258 $^{+8}_{-8}$	78 $^{+2.2}_{-2.9}$	—	—	—	1.5 $^{+0.5}_{-0.5}$	—	—	6.4 $^{+1.2}_{-1.4}$	—	13 $^{+1.2}_{-1.3}$	0.55 $^{+0.09}_{-0.11}$	—	0.64 $^{+0.32}_{-0.27}$	32.8 $^{+2.2}_{-2.7}$
PDS 543	333 $^{+4}_{-3}$	—	—	33 $^{+4.1}_{-4.5}$	51 $^{+4.4}_{-4.5}$	0.8 $^{+0.2}_{-0.2}$	4.5 $^{+0.5}_{-0.5}$	—	0.5 $^{+0.6}_{-0.4}$	—	9.4 $^{+0.5}_{-0.5}$	0.07 $^{+0.05}_{-0.05}$	—	—	27.6 $^{+1.7}_{-1.9}$
$\langle$ HBe $\rangle$	378 $\pm$ 26	20 $\pm$ 6.8	30 $\pm$ 8.1	9.2 $\pm$ 4.4	20 $\pm$ 6.4	1.7 $\pm$ 0.4	4.1 $\pm$ 0.8	1.7 $\pm$ 1.1	2.9 $\pm$ 1.0	0.6 $\pm$ 0.5	7.6 $\pm$ 0.8	0.15 $\pm$ 0.04	0.13 $\pm$ 0.06	0.13 $\pm$ 0.04	60.7 $\pm$ 4.7
$\langle$ HAe $\rangle$	379 $\pm$ 21	20 $\pm$ 4.6	23 $\pm$ 4.7	4.2 $\pm$ 2.2	33 $\pm$ 5.7	2.2 $\pm$ 0.3	5.5 $\pm$ 1.2	0.6 $\pm$ 0.2	3.6 $\pm$ 0.8	0.7 $\pm$ 0.2	5.7 $\pm$ 1.1	0.31 $\pm$ 0.06	0.75 $\pm$ 0.25	0.22 $\pm$ 0.06	52.1 $\pm$ 4.3

Notes. The small and large grains have volume equivalent radii of 0.1 and 1.5 μm respectively. The PAH and continuum contributions are given in percentages of the total flux of the 10 μm feature. The bottom rows represent the sample averaged numbers for the HBe stars and the HAe stars of [van Boekel et al. \(2005\)](#).

Fig. 9. Extinction-corrected spectra (black), the fitted continua (dashed green) and the complete compositional fits (thick orange).

circumstellar material that show spectral structure in the $10\mu\text{m}$ region. The only difference in our version of the routine is that it fits the three different PAH features at 8.6, 11.2, and $12.7\mu\text{m}$ independently. The extinction corrected spectra and their best fits are displayed in Fig. 9. The resulting mass fractions are given in Table 8. The small and large grains have volume equivalent radii of 0.1 and $1.5\mu\text{m}$ respectively. The targets LkH α 215 and Hen 3-1110 were omitted from the analysis because of their low S/N.

There are a few remarkable characteristics appearing in the compositional analysis. The $10\mu\text{m}$ features contain little

PAH emission, there is a fair amount of crystalline silicates and there is a notable presence of amorphous silica at $9\mu\text{m}$. In Sect. 7 we will put these characteristics into context when we compare the HBe sample to the HAe sample of van Boekel et al. (2005). R Mon will be excluded from the discussion of the silicates because of the large error bars, probably because of a substantial underestimation of the IR extinction. To check the influence of our extinction correction on the other sources, we also obtained compositional fits to the uncorrected spectra. We found that an underestimate of the extinction correction could lead to a slight overestimate of the crystallinity. PDS 27 turns out to be unusual,

because its $10\mu\text{m}$ feature does not show spectral structure. This most likely indicates the absence of grains smaller than a few micron.

We note strong [Ne II] emission at $12.81\mu\text{m}$ in the *Spitzer* and VISIR spectra of MWC 878 (Fig. 6). This line in the VISIR spectrum shows that it must originate in the immediate vicinity of the star. [Ne II] $12.81\mu\text{m}$ emission is also detected in a significant fraction ($\sim 20\%$) of T Tauri stars, where it has been interpreted as caused by X-ray excitation on the surface of a flared circumstellar disk (e.g. Lahuis et al. 2007; Pascucci et al. 2007). We note that MWC 878 is one of the earliest-type stars in our sample (O9/B0), suggesting that X-ray excitation may also be important for the line emission in these stars.

6.3. Spatial extent

The observed sizes as a function of wavelength as displayed in Fig. 7 are quite similar to the results found with the same method for H Ae stars (see Verhoeff 2009). The overall slopes are quite flat and no signature of the silicate feature can be identified. For some targets the size measured in the continuum is larger than the statistical PSF. An increase in size can be found in some targets at the wavelengths of the PAH emission features (PDS 204, MWC 147, Hen 3-331, Hen 3-847). Notable is the upturn to the left of $8.3\mu\text{m}$, which is associated with the $7.7\text{--}7.9\mu\text{m}$ PAH complex. There are also slight increases in extent at 8.6 and $11.2\mu\text{m}$, which are associated with the C-H in plane and C-H out of plane bending modes of the PAH molecule, respectively.

To obtain the intrinsic sizes of the sources, we quadratically subtracted of the statistical PSF for every setting and in every wavelength bin. The error for the absolute scale of every setting was then derived by numerical propagation of the measurement errors and the error on the statistical PSF. Subsequently, we defined the continuum size of a particular target as the mean of the median values of all settings. In this way we used all settings as semi-independent measurements of the N -band size and filtered out the size increases caused by PAH emission.

For the sources that contained a significant increase in FWHM at the wavelength of the 8.6 and $11.2\mu\text{m}$ PAH features, we retrieved the intrinsic scale of the PAH emission by decomposing the spatial emission profile at the central wavelength of the features. We first determined the underlying continuum profile from the 2D spectrum. This was achieved by extracting the spatial emission profiles just outside the wavelength range of the PAH features. We averaged these profiles and then scaled the flux level to the continuum flux level as determined with the VISIR flux spectra. We then subtracted this continuum profile from the spatial profile at the central wavelength of the PAH feature. We fitted a Gaussian to the remaining “pure” PAH profiles to obtain the FWHM size. Finally, we quadratically subtracted the statistical PSF. In Table 9 we report the results of all analyses. For sources with a significant PAH flux feature (Table 8), but no significant change in FWHM, we state the continuum size for that feature. For a more detailed description of the applied methods we refer the reader to Verhoeff (2009).

6.4. Differential extractions

For a few objects it was possible to extract more than one spectrum. This provides information about the spatial distribution of different dust species and PAH molecules. For PDS 204, we extracted a five pixel wide trace through the central component and a trace through the attached emission patch $1.7''$ south-southeast

Fig. 10. VISIR spectra of PDS 204. A five pixel trace through the central component (black) and a five pixel trace through the patch $1.7''$ southeast of the center (green).

Fig. 11. VISIR spectra of AS 310. A five pixel trace through the central component (black), a five pixel trace through the peripheral background $1''$ north of the primary (blue) and a five pixel trace through the secondary component $4.6''$ north of the primary (dotted red).

of the target. Figure 10 shows them overplotted. The emission patch ~ 1700 AU away from the star generates the same amount of flux in the continuum-subtracted $11.2\mu\text{m}$ PAH feature.

The large spatial scale (diameter ~ 0.05 pc) of the continuum emission of AS 310 is very peculiar (see Fig. 5). The nature of this emission is not clear. In Fig. 11 we display five-pixel-wide traces through the primary source, the background $1''$ north of the primary, and the secondary component $4.6''$ north of AS 310. The primary has a distinct silicate feature, whose shape suggests significant grain processing (crystallization and/or grain growth), which is commonly observed in disks. However, the large continuum size in the imaging and in the spectrum (Table 9) seems to suggest we are looking at a huge cloud of dust. The secondary component does not seem to display a silicate feature. The deficit of PAH emission in either of the components or the background is also puzzling (compare Fig. 10). Note that in the optical, this source also has quite

Table 9. Deconvolved FWHM sizes of our targets in the spectroscopic mode.

Name	Continuum		8.6 μm		11.2 μm		Disk PAH?	Cloud PAH?
	[$''$]	[AU]	[$''$]	[AU]	[$''$]	[AU]		
PDS 204	<0.38	<390	$1.61^{+0.11}_{-0.11}$	1610	$2.25^{+0.03}_{-0.03}$	2240	?	y
MWC 789	<0.62	<430	–	–	–	–	y	n
LkH α 208	<0.57	<580	<0.57	<580	–	–	y	n
LkH α 339	<0.75	<630	–	–	–	–	y	n
MWC 137	<0.55	<710	<0.55	<710	–	–	y	y
LkH α 215	<0.88	<710	–	–	–	–	y	?
MWC 147	<0.37	<300	–	–	$2.02^{+0.35}_{-0.36}$	1610	?	y
R Mon	<0.58	<460	–	–	–	–	?	y
PDS 27	<0.47	<600	–	–	–	–	y	n
Hen 3-331	<0.56	<840	$0.41^{+0.05}_{-0.06}$	600	–	–	y	n
Hen 3-847	<0.54	<890	$0.48^{+0.31}_{-0.16}$	810	$0.51^{+0.06}_{-0.08}$	840	y	y
Hen 3-1110	<0.67	<440	–	–	–	–	y	?
V921 Sco	<0.54	<620	<0.54	<620	–	–	y	y
MWC 878	<0.48	<1600	–	–	–	–	y	n
PDS 477	<0.36	<2430	<0.36	<2430	–	–	y	y
LkH α 260	<0.53	<1120	–	–	–	–	n	y
MWC 297	<0.55	<140	<0.55	<140	–	–	y	y
AS 310	$1.15^{+0.05}_{-0.05}$	2870	$1.15^{+0.05}_{-0.05}$	2870	–	–	?	y
PDS 543	<0.62	<1730	–	–	–	–	y	?

Notes. The corresponding sizes in AU were obtained with the distances of Table 1. The last two columns indicate the inferred origin of PAH emission.

prominent nebulosity. How the distribution of material can generate the observed mid-IR features is not clear.

7. Discussion

7.1. IR excess

The HAe stars are relatively isolated, but for the HBe stars the IRAS, MSX, and 2MASS photometry contains contributions from the surrounding molecular cloud ($\gtrsim 1''$). Therefore a classification of the HBe objects based on wide-field photometry is not always meaningful. The VISIR observations help to isolate the mid-IR emission from the immediate vicinity of the star and provides more clarity on the nature of the objects. Of our original sample (see Table 1) four sources were not even detected in the VISIR imaging (indicated with a †). These sources (Hilt 641, AS 267, NGC 6530-45, and LkH α 112) do not have a compact IR excess. The emission detected by IRAS is either caused by an unrelated nearby source, or by diffuse interstellar matter heated by the star. Another six sources (#) had a 12 μm excess as seen by VISIR that was too faint for spectroscopic follow-up (PDS 241, MCW 1264, Hen 3-1418, PDS 152, MWC 593, and LkH α 115). These sources are unlikely to possess a significant amount of circumstellar dust. This is also valid for LkH α 215 and Hen 3-1110, albeit to a lesser extent. In Sect. 7.4 we will discuss the nature of the sources in more detail. For now we focus on the sources that do have a compact IR excess and for which we were therefore able to obtain VISIR spectra (see Fig. 6).

The IR excess emission of all of these sources starts in the near-IR and extends to the far-IR. Figure 1 displays the wide variety of shapes that is observed. There are declining SEDs (e.g. Hen 3-331), flat SEDs (e.g. PDS 27), and rising SEDs (e.g. LkH α 339). Some SEDs show a broad bump that peaks around 10 μm (e.g. Hen 3-847). We must keep in mind, though, that

most of these targets are still shrouded in their natal clouds, which significantly contributes to the mid- and far-IR fluxes. With the higher spatial resolution of VISIR we are in most cases capable of isolating the emission of the circumstellar disk. The contrast is illustrated in Fig. 1. The red triangles represent our VISIR photometric results at 12 μm (see Sect. 5.1). Sources with an obvious substantial environmental contribution include LkH α 339, LkH α 215, LkH α 241, and AS 310. Even with the VISIR photometry it is difficult to classify the disk in terms of flaring or flat disk geometries (Meeus et al. 2001). This requires additional high spatial resolution photometry at longer wavelengths. In the last column of Table 1 we indicated our classification into group I, II, G, and U. The “G” stands for gas-disk (see Sect. 7.4) and the “U” for uncertain. This latter classification is needed because it is not possible to discriminate between a flaring disk and a flat disk plus cloud contribution. Note that as a consequence, we cannot identify group I sources in our sample.

The collection of shapes of the IR excess of the HBe stars resembles those that we see for the lower mass HAe stars (see Meeus et al. 2001). A noticeable difference, however, is that the average IR excess is weaker for the HBes, and that the sample contains a higher diversity. The median near-IR excess in the HAe sample of Verhoeff (2009) is a factor 8 higher than the median value of our HBe sample. The spread is also notably different; it is twice as extended in the HBe sample. The far-IR excess in the IRAS 60 and 100 μm bands, on the other hand is higher on average for the HBe stars, and their spread is much wider. This can be explained with cloud contributions, as mentioned before. For the comparison of the IR excess at 12 μm we are able to consider the emission from the disk only. In Fig. 12 we plotted the 12 μm luminosity, L_{12} , against the stellar luminosity for the HAe sample of van Boekel et al. (2005) and for our HBe sample. The L_{12} was calculated from the distance, d , and the IRAS 12 μm flux for HAe stars and the VISIR SiC flux for the HBe stars (F_{12})

Fig. 12. $12\mu\text{m}$ luminosities against the stellar luminosities for the H Ae sample of van Boekel et al. (2005; open blue squares) and our H Be sample (filled red triangles). A dashed line with slope unity is added to guide the eye. The errors for the H Ae's are all smaller than the plotting symbols.

as follows: $L_{12} = 4\pi \cdot d^2 \cdot F_{12} \cdot \Delta\nu$, where we set $\Delta\nu$ equal to the bandwidth in Hz of the SiC filter (see Table 3) for both samples. The plot shows that the average L_{12} increases with stellar luminosity, but the typical reprocessing power, L_{12}/L_* , decreases with stellar luminosity. The median reprocessing at $12\mu\text{m}$ is a factor 5 smaller for the H Be stars than for the H Ae stars. This is also true for the total IR reprocessing power. From the literature photometry we obtain a median L_{IR}/L_* of 45% for the H Aes and only 15% for the H Bes. A correction for cloud contribution would lower the latter even more. This result was already observed for one particular H Be star: [Acke et al. \(2008\)](#) found that the total IR excess of MWC 297 is only $L_{\text{IR}}/L_* \sim 5\%$.

We interpret the differences in the IR SEDs of the H Be and H Ae stars as geometrical differences of their disks. The lower total IR reprocessing power (see Fig. 1) is directly related to a narrower covering angle of the disk. The lower near-IR reprocessing corresponds to a lesser contribution from the hot inner part of the disk. This suggests that the inner disks of many H Be stars are flatter. This has also been demonstrated with IR interferometers for MWC 147 ([Kraus et al. 2008](#)) and MWC 297 ([Acke et al. 2008](#)). Corrected for cloud contribution, we would expect to find a lower far-IR reprocessing efficiency as well, corresponding to a lesser contribution from the outer disk. This would imply that the outer disk is also flatter and/or that the magnitude of the outer radius has been reduced. The latter is consistent with predictions from photoevaporation theory ([Gorti & Hollenbach 2009](#)), which suggest that the higher FUV flux from the central star decreases the dissipation time-scale of the outer disk considerably. The disks around H Be stars are apparently flatter and are probably truncated on the outside.

7.2. PAHs

The comparison of VISIR and *Spitzer*/ISO spectra illustrates nicely how observations taken with wide apertures can report a much higher PAH flux (see e.g. MWC 147 in Fig. 6). This raises the question whether the PAH emission comes from a circumstellar disk, from a surrounding nebula, or both. Combining the results of the analysis of the spectra and images, we can locate

Fig. 13. Reprocessing power of the PAH molecules against the stellar luminosity. Symbols have the same meaning as in Fig. 12.

the origin of the PAH emission. We indicate the results in the last two columns of Table 9. Where the data were not conclusive, we state added a question mark.

From the contrast with wide aperture spectra in Fig. 6 we know that PDS 204, MWC 137, MWC 147, Hen 3-847, V921 Sco, and MWC 297 display PAH from surrounding clouds, while LkH α 339, Hen 3-331, and MWC 878 do not. A comparison of the VISIR and IRAS photometry in Table 6 excludes MWC 789, LkH α 208, PDS 27, and MWC 878 from having any cloud emission in the mid-IR. A comparison of the VISIR imaging in the PAH2 filter and in the PAH2_2 filter confirms and adds a couple of sources to the list of cloud PAH emitters. For R Mon, PDS 27, V921 Sco, PDS 477, and LkH α 260 the imaging shows a weak cloud PAH component. PDS 204, MWC 147, and AS 310 display strong cloud PAH components (compare Figs. 4 and 5).

The VISIR spectra were extracted with a weight-map that emphasizes the spatially centered emission. They are therefore a relatively good tracer for the emission from disk-scales. We recall, though, that at 2 kpc the $0.4''$ slit still encompasses 800 AU. By taking spectra at different locations we compared the PAH contribution from the central component and the surrounding cloud (see Figs. 10–11). The PAH components from the centers of these sources are not stronger than those of their surrounding media. Furthermore, the deconvolved sizes of the PAH emission have quite high values for these sources. This could mean that the PAH emission at the center of these sources is foreground emission from an envelope and not from a circumstellar disk. Of course, observations of even higher spatial resolution are required to clarify this matter. For now we will assume all the PAH emission in the VISIR spectra has a disk origin. The individual PAH bands were not all significantly detected. However, the total flux in the 8.6, 11.2, and $12.7\mu\text{m}$ PAH bands together turned out to be significant for all sources in Table 8, with the exception of LkH α 260.

In Fig. 13 we plot the logarithm of F_{PAH}/F_* , the total flux in the 8.6, 11.2, and $12.7\mu\text{m}$ PAH bands divided by the stellar flux as a function of the stellar luminosity. The plot includes the H Ae sample of van Boekel et al. (2005; open blue squares). It shows a trend of a decreasing PAH reprocessing power with increasing luminosity of the star. However, when we plot the F_{PAH} relative to F_{12} , we see that the ratio of the PAH and IR reprocessing powers is roughly constant (see Fig. 14). The lower

Fig. 14. PAH strength relative to the $12\mu\text{m}$ flux as a function of the stellar luminosity. Symbols have the same meaning as in Fig. 12.

PAH contribution from the disks of HBe stars could entirely be ascribed to smaller outer radii and/or more narrow covering angles of the HBe disks that we argued for in Sect. 7.1. The outer disk is known to deliver the dominant contribution to the PAH emission of the integrated flux spectrum. Observations of HAe stars also show that flatter disks have weaker PAH reprocessing powers (Meeus et al. 2001; Acke et al. 2004; Habart et al. 2004; Acke et al. 2010). We conclude that there is no clear evidence for a decreasing PAH abundance with increasing stellar luminosity.

7.3. Silicates

We have compared the silicate composition of our HBe sources as displayed in Table 8 (R Mon excluded) with the HAe sample of van Boekel et al. (2005). From Figs. 6 and 9 it is already clear that the overall silicate composition of the HBe stars is very similar to that of the HAe stars. Here we address the subtle differences that we did find.

Figure 15 shows that for the HAe stars the crystallinity is typically low ($\sim 5\%$). However, those sources for which the large grain component is particularly abundant ($>80\%$) can have much higher crystallinity fractions. The HBe stars do not show this behavior. The average crystallinity fraction is slightly lower in the large-grain domain than in the small-grain domain. On the whole, the average crystallinity fraction is similar (8% versus 12% for the HAes). Within the margin of the errors this conclusion is independent of the extinction correction.

We find that for a typical HBe star the mass fraction of enstatite, amorphous silica, and forsterite is similar to that of a typical HAe star. At low forsterite abundances ($<4\%$) we do see a difference, however, (see Fig. 16). The amorphous silica abundance is seven times higher in that range for the HBe stars. More generally it seems that the positive correlation between silica and forsterite for HAe stars, found by van Boekel et al. (2005), is no longer present for the HBe stars. The presence of this correlation was predicted by experiments that show that amorphous silica can be formed as a by-product in the annealing process of enstatite to forsterite (see e.g. Rietmeijer et al. 1986; Fabian et al. 2000). In this scenario, enstatite (MgSiO_3), silica (SiO_2), and forsterite (Mg_2SiO_4) are connected by the chemical equilibrium reaction

Fig. 15. Mass fraction in crystalline grains against the mass fraction in large ($1.5\mu\text{m}$) grains as derived from our compositional fits. Symbols have the same meaning as in Fig. 12.

Fig. 16. Mass fraction in amorphous silica and forsterite grains. Symbols have the same meaning as in Fig. 12.

Sargent et al. (2009) suggested that in protoplanetary disks this reaction takes place via incongruent melting. In this context it is very interesting that we do not find such a correlation between silicate and forsterite for the HBe stars (see Fig. 16). Maybe the silica in HBe stars is predominantly formed as a primary condensation product of MgO-SiO_2 vapor in non-equilibrium conditions (Rietmeijer et al. 1999). This suggests that the high silica fractions in the HBe disks with low forsterite abundances reflect a history of dust vaporization followed by condensation.

7.4. Relation to B[e] and classical Be stars

Several classes of hot B-type stars exist that show permitted and/or forbidden emission lines in their optical spectra, and an IR excess caused by circumstellar gas and/or dust. Apart from the HBe stars discussed in this paper, the B[e] supergiants and the classical Be stars can show observational characteristics that are similar to those of HBe stars. We refer to Lamers et al. (1998) for a more complete discussion of this topic. B[e] supergiants are evolved, probably rapidly rotating high-mass stars

with highly stratified outflows, a fast ionized wind at the poles and a slow, dusty outflow at the equator (Zickgraf et al. 1985). Their IR SEDs show a wide range of dust temperatures, similar to what is expected from disks surrounding young pre-main-sequence stars. The luminosities of B[e] supergiants in the LMC have been well established, and are typically in the range 10^5 to $10^6 L_{\odot}$, with a few cases at lower luminosities (Zickgraf et al. 1986). The luminosities estimated for our sample of HBe stars are significantly lower, and so we conclude that it is unlikely that our sample is strongly contaminated by B[e] supergiants.

Classical Be stars are rapidly rotating main-sequence stars or giants with circumstellar gas located in a dense equatorial disk (Porter & Rivinius 2003). No forbidden emission lines are seen in the optical, and the IR excess is caused by free-free and bound-free emission from the gas in the disk. The mid-IR spectra of these stars typically show a power-law continuum with hydrogen recombination line emission superposed (Hony et al. 2000). There is not much evidence for dust in disks surrounding classical Be stars. The density in the disk is probably insufficient to form molecules and dust. The IR excess of classical Be stars at $12\mu\text{m}$ is modest, typically up to 2.5 mag (Waters 1986), and much weaker than in disks surrounding HBe stars. In our sample we found some stars with a strong $12\mu\text{m}$ excess based on IRAS photometry, but a much lower flux based on high spatial resolution VISIR mid-IR imaging, corresponding to a much weaker IR excess (see Table 6). These are LkH α 215, PDS 241, Hen 3-1110, MCW 1264, Hen 3-1418, PDS 152, MWC 593, and LkH α 115. Considering the SEDs, these stars might be classical Be stars rather than HBe stars (see e.g. LkH α 215 and PDS 241 in Fig. 1). Unfortunately, these sources are too weak in the mid-IR to conclusively establish the nature of their IR excess with VISIR spectroscopy. The shape of the feeble spectra of LkH α 215 and Hen 3-1110 are compatible, however, with free-free and bound-free emission from gas rather than the more typical dust-dominated spectra seen in the other studied targets (hence the “G” label in Table 1). It would be interesting to confirm that these are indeed classical Be stars in star-forming regions, because it would show that B type stars can rotate close to their break-up speed at a very young age (see also Ake et al. 2008).

A final remark concerns massive interacting binaries. These systems may also show a dusty disk around one of the stars in the system, or around the binary. However, these evolutionary phases are rare and we do not expect that our sample is significantly contaminated with such systems.

7.5. Emerging picture

The mid-IR imaging of our HBe stars revealed compact circumstellar material, most likely distributed in disks. The SEDs of the HBe stars display a higher diversity of IR excess shapes than the HAe stars. Also, the total IR excess is less prominent on average than that of the HAe stars. We interpret these differences as a variation in cloud contributions and geometrical differences of the disks. The disks around HBe stars are flatter and likely truncated on the outside. The typical disk size was constrained with the VISIR spectra to a FWHM upper limit of ~ 500 AU. For comparison, Verhoeff (2009) found a typical FWHM of ~ 50 AU for the HAes using the same method. These observations question the notion that the disks of HBe are scaled up versions of HAe stars. The observed $10\mu\text{m}$ features show that the mineralogy of these disks is quite similar to that of their lower mass Ae counterparts. Just as for the HAes, we detect amorphous silicates, crystalline silicates, and emission from PAHs.

Noteworthy differences are the IR extinction (e.g. MWC 297), the absence of a relation between the abundance of amorphous silica and forsterite, the lower contribution of PAH emission (e.g. MWC 147), and an absence of PAH-dominated sources.

The flux-levels, the spatial compactness and the underlying dust composition all point to the fact that, as for the HAe stars, the IR emission of Herbig Be stars is typically characterized by a circumstellar disk that efficiently reprocesses a substantial portion of the stellar flux. The picture described above of the HBe disks as being truncated is consistent with modeling results of Gorti & Hollenbach (2009), who find that FUV photo-evaporation predominantly removes gas from the outer disk and that more luminous stars lose their disks rapidly. This could also explain the absence of a silica-forsterite relation, because this would require a fair deal of dust evaporation followed by condensation. Furthermore, it can explain the lower PAH flux contribution we found, because this emission is known to come from radii larger than the thermal silicate emission (see e.g. Habart et al. 2004; van Boekel et al. 2004; Lagage et al. 2006; Visser et al. 2007; Verhoeff 2009).

8. Conclusions

We have composed SEDs from literature photometry and have derived stellar parameters for a sample of HBe stars. We performed *N*-band imaging and long-slit spectroscopy with VISIR at the VLT. We analyzed these data to determine the composition and geometry of the circumstellar dust. The main conclusions we can draw from the results of our study can be summarized as follows:

- The HBe stars are surrounded by nebulae that manifest themselves in increased optical extinction, a difference between VISIR and IRAS photometry, strong far-IR excess, high PAH flux of wide field spectroscopy, and large spatial extent of the PAH emission in VISIR spectroscopy.
- The IR emission of the HBe stars can be characterized by a circumstellar disk that efficiently reprocesses a substantial portion of the stellar flux.
- The disks around HBe stars appear to be comparable to those around the lower mass HAe counterparts in terms of flux levels, mineralogy, and spatial compactness.
- Compared to HAe stars, HBes typically have a weaker overall IR excess, and the sample contains a higher variety of IR excess shapes.
- The $12\mu\text{m}$ reprocessing power, L_{12}/L_{*} , of Herbig Ae/Be stars goes down with stellar luminosity.
- The $10\mu\text{m}$ spectra show that HBes have similar silicate abundances to those of the HAes.
- The disks around HBe stars generally have a lower PAH reprocessing power, F_{PAH}/F_{*} , than HAe disks.
- The abundance of PAH molecules does not have to be different for disks around HBe and HAe stars.
- The $10\mu\text{m}$ spectra of the HBes do not show a relation between the mass fraction in crystalline grains and the mass fraction in large grains, as is the case for HAe stars.
- The $10\mu\text{m}$ spectra of the HBes do not show a relation between the abundance of amorphous silica and forsterite, suggesting a history of dust vaporization followed by dust condensation.
- In the spectroscopic mode we spatially resolved 5 out of 17 HBe stars in either the continuum or in the 8.6 or $11.2\mu\text{m}$ PAH-bands.

- We find upper limits to the mid-IR FWHM size of typically ~ 500 AU.
- On the basis of the low mid-IR fluxes in our high spatial resolution photometry of LkH α 215, PDS 241, Hen 3-1110, MCW 1264, Hen 3-1418, PDS 152, MWC 593, and LkH α 115, it is possible that these stars are classical Be stars rather than HBe stars.
- The shape of the IR SED, the lower $12\mu\text{m}$ reprocessing power, the weaker PAH emission, and the lack of a silica-forsterite relation can all be explained by assuming that HBes have flatter disks than the HAes and that they are truncated on the outside by photoevaporation.

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Table 4. Log of the entire VISIR *N*-band imaging ordered according to observation date.

Target	Filter	Orient. [°]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing [″]	Int.time [s]	Category
HD 198048	PAH2	0	9	2006-10-06	00:12	1.08	0.90	110	CAL
HD 198048	SIC	0	9	2006-10-06	00:15	1.08	0.85	109	CAL
HD 198048	PAH2_2	0	9	2006-10-06	00:18	1.08	0.88	109	CAL
HD 198048	SIC	0	9	2006-10-06	01:26	1.10	0.92	109	CAL
HD 198048	SIC	0	9	2006-10-06	02:08	1.14	0.94	109	CAL
HD 26967	PAH2	0	9	2006-10-06	07:29	1.05	0.87	110	CAL
HD 26967	SIC	0	9	2006-10-06	07:32	1.05	0.79	109	CAL
HD 26967	PAH2_2	0	9	2006-10-06	07:35	1.05	0.72	109	CAL
PDS204	SIC	96	30	2006-10-06	07:56	1.68	1.06	171	SCI
PDS204	PAH2	96	30	2006-10-06	08:01	1.66	1.04	173	SCI
PDS204	PAH2_2	96	30	2006-10-06	08:05	1.65	1.01	172	SCI
MWC789	SIC	60	30	2006-10-06	08:17	1.44	0.91	171	SCI
MWC789	PAH2	60	30	2006-10-06	08:21	1.43	0.84	173	SCI
MWC789	PAH2_2	60	30	2006-10-06	08:25	1.42	0.89	172	SCI
LkHa208	SIC	85	30	2006-10-06	08:39	1.45	1.04	171	SCI
LkHa208	PAH2	85	30	2006-10-06	08:43	1.44	0.98	173	SCI
LkHa208	PAH2_2	85	30	2006-10-06	08:48	1.43	1.00	172	SCI
LkHa339	SIC	160	30	2006-10-06	09:01	1.08	0.70	171	SCI
LkHa339	PAH2	160	30	2006-10-06	09:05	1.07	0.68	173	SCI
LkHa339	PAH2_2	160	30	2006-10-06	09:09	1.07	0.71	172	SCI
HD 33554	PAH2	0	9	2006-10-06	09:21	1.33	0.94	110	CAL
HD 33554	SIC	0	9	2006-10-06	09:25	1.33	1.00	109	CAL
HD 33554	PAH2_2	0	9	2006-10-06	09:28	1.34	1.04	109	CAL
HD 49968	PAH2	0	9	2006-10-06	09:39	1.55	1.29	110	CAL
HD 49968	SIC	0	9	2006-10-06	09:42	1.54	1.85	109	CAL
HD 49968	PAH2_2	0	9	2006-10-06	09:46	1.54	2.29	109	CAL
HD 41047	PAH2	0	9	2006-12-05	05:08	1.02	0.98	110	CAL
HD 41047	SIC	0	9	2006-12-05	05:11	1.02	0.99	109	CAL
HD 41047	PAH2_2	0	9	2006-12-05	05:15	1.02	0.96	109	CAL
MWC137	SIC	45	30	2006-12-05	05:26	1.32	1.45	171	SCI
MWC137	PAH2	45	30	2006-12-05	05:30	1.32	1.40	173	SCI
MWC137	PAH2_2	45	30	2006-12-05	05:35	1.31	1.39	172	SCI
LkHa215	SIC	90	30	2006-12-05	05:45	1.23	1.27	171	SCI
LkHa215	PAH2	90	30	2006-12-05	05:49	1.23	1.14	173	SCI
LkHa215	PAH2_2	90	30	2006-12-05	05:53	1.22	1.12	172	SCI
MWC147	SIC	45	30	2006-12-05	06:03	1.22	1.18	171	SCI
MWC147	PAH2	45	30	2006-12-05	06:08	1.22	1.18	173	SCI
MWC147	PAH2_2	45	30	2006-12-05	06:12	1.22	1.26	172	SCI
RMon	SIC	90	30	2006-12-05	06:22	1.20	1.46	171	SCI
RMon	PAH2	90	30	2006-12-05	06:26	1.20	1.30	173	SCI
RMon	PAH2_2	90	30	2006-12-05	06:31	1.20	1.23	172	SCI
HD 26967	PAH2	0	9	2006-12-05	06:42	1.27	1.21	110	CAL
HD 26967	SIC	0	9	2006-12-05	06:46	1.28	1.20	109	CAL
HD 26967	PAH2_2	0	9	2006-12-05	06:49	1.29	1.24	109	CAL
PDS241	SIC	45	30	2006-12-05	07:24	1.08	1.12	171	SCI
PDS241	PAH2	45	30	2006-12-05	07:31	1.08	1.20	173	SCI
PDS241	PAH2_2	45	30	2006-12-05	07:36	1.09	1.05	172	SCI
PDS27	SIC	0	30	2006-12-05	07:47	1.02	0.90	171	SCI
PDS27	PAH2	0	30	2006-12-05	07:51	1.03	0.89	173	SCI
PDS27	PAH2_2	0	30	2006-12-05	07:56	1.03	1.01	172	SCI
HD 75691	PAH2	0	9	2006-12-05	08:22	1.00	1.05	110	CAL
HD 75691	SIC	0	9	2006-12-05	08:25	1.00	1.07	109	CAL
HD 75691	PAH2_2	0	9	2006-12-05	08:29	1.00	0.98	109	CAL
HD 41047	PAH2	0	9	2007-01-13	02:47	1.02	0.71	110	CAL
Hen3331	SIC	135	30	2007-01-13	04:14	1.44	1.16	172	SCI
Hen3331	PAH2	135	30	2007-01-13	04:19	1.43	1.16	173	SCI
Hen3331	PAH2_2	135	30	2007-01-13	04:23	1.42	1.12	173	SCI
Hen3331	SIC	135	30	2007-01-13	04:28	1.40	1.08	173	SCI
HD 89682	PAH2	0	9	2007-01-13	04:43	1.37	0.96	110	CAL
HD 89682	SIC	0	9	2007-01-13	04:46	1.36	0.87	110	CAL
HD 89682	PAH2_2	0	9	2007-01-13	04:50	1.35	0.87	110	CAL
HD 111915	PAH2	0	9	2007-01-13	06:24	1.52	1.07	110	CAL
HD 111915	SIC	0	9	2007-01-13	06:27	1.50	1.03	110	CAL
HD 111915	PAH2_2	0	9	2007-01-13	06:31	1.48	1.06	110	CAL
HD 111915	PAH2	0	9	2007-01-13	07:23	1.30	0.93	110	CAL
HD 111915	SIC	0	9	2007-01-13	07:27	1.29	0.98	110	CAL

Table 4. continued.

Target	Filter	Orient. [°]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing ["]	Int.time [s]	Category
HD 111915	PAH2_2	0	9	2007-01-13	07:30	1.28	1.11	110	CAL
HD 111915	PAH2	0	9	2007-01-13	07:34	1.27	1.09	110	CAL
HD 111915	SIC	0	9	2007-01-13	07:37	1.26	1.13	109	CAL
HD 111915	PAH2_2	0	9	2007-01-13	07:40	1.25	1.12	110	CAL
Hen3331	PAH2_2	135	30	2007-01-13	07:51	1.26	1.04	173	SCI
Hen3847	SIC	70	30	2007-01-13	08:02	1.22	0.91	172	SCI
Hen3847	PAH2	70	30	2007-01-13	08:06	1.21	1.14	173	SCI
Hen3847	PAH2_2	70	30	2007-01-13	08:11	1.20	1.07	173	SCI
HD 41047	PAH2	0	9	2007-02-28	00:17	1.01	0.79	110	CAL
Hen31110	SIC	0	30	2007-02-28	09:22	1.17	0.89	173	SCI
Hen31110	PAH2	0	30	2007-02-28	09:27	1.17	0.83	173	SCI
HD 145897	PAH2	0	9	2007-02-28	09:45	1.04	1.17	110	CAL
HD 145897	SIC	0	9	2007-02-28	09:48	1.04	1.06	110	CAL
HD 145897	PAH2_2	0	9	2007-02-28	09:51	1.03	1.11	110	CAL
HD 123123	PAH2	0	9	2007-03-04	06:49	1.04	0.63	110	CAL
HD 123123	SIC	0	9	2007-03-04	06:53	1.04	0.66	109	CAL
HD 123123	PAH2_2	0	9	2007-03-04	06:56	1.03	0.75	110	CAL
HD 123123	PAH2	0	9	2007-03-04	07:02	1.03	0.74	110	CAL
HD 123123	SIC	0	9	2007-03-04	07:05	1.02	0.66	110	CAL
HD 123123	PAH2_2	0	9	2007-03-04	07:08	1.02	0.64	110	CAL
MWC1264	SIC	0	30	2007-03-04	07:52	1.30	0.73	173	SCI
MWC1264	PAH2	0	30	2007-03-04	07:56	1.28	0.74	173	SCI
MWC1264	PAH2_2	0	30	2007-03-04	08:01	1.27	0.76	173	SCI
V921Sco	SIC	0	30	2007-03-04	08:30	1.21	0.80	173	SCI
V921Sco	PAH2	0	30	2007-03-04	08:34	1.20	0.84	173	SCI
V921Sco	PAH2_2	0	30	2007-03-04	08:39	1.19	0.81	173	SCI
MWC878	SIC	0	30	2007-03-04	08:53	1.20	0.80	173	SCI
MWC878	PAH2	0	30	2007-03-04	08:57	1.19	0.84	173	SCI
MWC878	PAH2_2	0	30	2007-03-04	09:02	1.18	0.76	173	SCI
HD 163376	PAH2	0	9	2007-03-04	09:19	1.23	1.19	110	CAL
HD 163376	SIC	0	9	2007-03-04	09:22	1.22	1.02	110	CAL
HD 163376	PAH2_2	0	9	2007-03-04	09:25	1.21	1.11	110	CAL
HD 145897	PAH2	0	9	2007-03-04	09:39	1.03	0.81	110	CAL
HD 145897	SIC	0	9	2007-03-04	09:42	1.03	0.86	110	CAL
HD 145897	PAH2_2	0	9	2007-03-04	09:46	1.03	0.81	110	CAL
HD 41047	PAH2	0	9	2007-03-06	00:54	1.05	0.76	110	CAL
HD 41047	SIC	0	9	2007-03-06	00:58	1.05	0.82	109	CAL
HD 41047	PAH2_2	0	9	2007-03-06	01:01	1.05	0.81	110	CAL
HD 139663	PAH2	0	9	2007-03-06	08:47	1.01	0.99	110	CAL
HD 139663	SIC	0	9	2007-03-06	08:51	1.01	0.89	110	CAL
HD 139663	PAH2_2	0	9	2007-03-06	08:54	1.01	0.90	110	CAL
Hen31418	SIC	0	30	2007-03-06	09:20	1.12	1.02	173	SCI
Hen31418	PAH2	0	30	2007-03-06	09:24	1.11	1.03	173	SCI
Hen31418	PAH2_2	0	30	2007-03-06	09:29	1.11	1.01	173	SCI
HD 163376	PAH2	0	9	2007-03-06	09:41	1.16	1.04	110	CAL
HD 163376	SIC	0	9	2007-03-06	09:44	1.15	1.05	110	CAL
HD 163376	PAH2_2	0	9	2007-03-06	09:48	1.15	1.00	110	CAL
HD 99167	PAH2	0	9	2007-03-10	07:06	1.21	1.00	110	CAL
HD 99167	SIC	0	9	2007-03-10	07:09	1.22	0.88	109	CAL
HD 99167	PAH2_2	0	9	2007-03-10	07:13	1.23	0.96	110	CAL
Hen3847	SIC	160	30	2007-03-10	07:22	1.12	0.78	172	SCI
Hen3847	PAH2	160	30	2007-03-10	07:32	1.12	0.84	173	SCI
Hen3847	PAH2_2	160	30	2007-03-10	07:36	1.13	0.79	173	SCI
HD 145897	PAH2	0	9	2007-04-14	07:58	1.03	0.70	110	CAL
HD 145897	SIC	0	9	2007-04-14	08:01	1.04	0.77	109	CAL
HD 145897	PAH2_2	0	9	2007-04-14	08:05	1.04	0.84	109	CAL
HD 145897	PAH2	0	9	2007-04-14	08:11	1.04	0.77	110	CAL
HD 145897	SIC	0	9	2007-04-14	08:14	1.05	0.95	109	CAL
HD 145897	PAH2_2	0	9	2007-04-14	08:17	1.05	0.82	110	CAL
PDS477	SIC	0	30	2007-04-14	08:29	1.02	0.91	172	SCI
PDS477	PAH2	0	30	2007-04-14	08:33	1.02	0.98	173	SCI
PDS477	PAH2_2	0	30	2007-04-14	08:37	1.02	0.91	173	SCI
NGC6611494	SIC	0	30	2007-04-14	08:50	1.03	0.88	172	SCI
NGC6611494	PAH2	0	30	2007-04-14	08:54	1.03	0.83	173	SCI
NGC6611494	PAH2_2	0	30	2007-04-14	08:58	1.03	0.94	173	SCI
MWC297	SIC	0	30	2007-04-14	09:09	1.08	0.89	172	SCI

Table 4. continued.

Target	Filter	Orient. [°]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing ["]	Int.time [s]	Category
MWC297	PAH2	0	30	2007-04-14	09:16	1.07	2.02	173	SCI
MWC297	PAH2_2	0	30	2007-04-14	09:20	1.07	1.62	173	SCI
V921Sco	SIC	0	30	2007-04-19	06:26	1.10	1.02	172	SCI
V921Sco	PAH2	0	30	2007-04-19	06:30	1.10	1.01	173	SCI
V921Sco	PAH2_2	0	30	2007-04-19	06:35	1.09	0.99	173	SCI
HD 139663	PAH2	0	9	2007-04-19	06:52	1.00	0.75	110	CAL
HD 139663	SIC	0	9	2007-04-19	06:55	1.00	0.72	109	CAL
HD 139663	PAH2_2	0	9	2007-04-19	06:59	1.01	0.77	110	CAL
MWC878	SIC	0	30	2007-04-19	07:09	1.06	1.02	172	SCI
MWC878	PAH2	0	30	2007-04-19	07:13	1.06	0.85	173	SCI
MWC878	PAH2_2	0	30	2007-04-19	07:17	1.06	0.89	173	SCI
Hen31444	SIC	0	30	2007-04-19	07:27	1.05	0.87	172	SCI
Hen31444	PAH2	0	30	2007-04-19	07:31	1.04	0.90	173	SCI
Hen31444	PAH2_2	0	30	2007-04-19	07:36	1.04	0.82	173	SCI
MWC593	SIC	0	30	2007-04-19	07:45	1.03	0.85	172	SCI
MWC593	PAH2	0	30	2007-04-19	07:49	1.02	0.93	173	SCI
MWC593	PAH2_2	0	30	2007-04-19	07:53	1.02	0.88	173	SCI
PDS152	SIC	0	30	2007-04-19	08:02	1.01	0.93	172	SCI
PDS152	PAH2	0	30	2007-04-19	08:07	1.01	0.90	173	SCI
PDS152	PAH2_2	0	30	2007-04-19	08:11	1.00	0.79	173	SCI
HD 163376	PAH2	0	9	2007-04-19	08:23	1.05	0.82	110	CAL
HD 163376	SIC	0	9	2007-04-19	08:26	1.05	0.73	109	CAL
HD 163376	PAH2_2	0	9	2007-04-19	08:29	1.05	0.72	110	CAL
AS310	SIC	0	30	2007-04-19	08:39	1.08	0.78	172	SCI
AS310	PAH2	0	30	2007-04-19	08:43	1.08	0.86	173	SCI
AS310	PAH2_2	0	30	2007-04-19	08:47	1.08	0.94	173	SCI
PDS543	SIC	0	30	2007-04-19	08:56	1.15	1.00	172	SCI
PDS543	PAH2	0	30	2007-04-19	09:00	1.14	0.99	173	SCI
PDS543	PAH2_2	0	30	2007-04-19	09:05	1.14	1.07	173	SCI
PDS543	SIC	0	30	2007-04-19	09:09	1.14	1.13	172	SCI
NGC6530245	SIC	0	30	2007-04-19	09:26	1.01	0.78	172	SCI
NGC6530245	PAH2	0	30	2007-04-19	09:30	1.01	0.77	173	SCI
NGC6530245	PAH2_2	0	30	2007-04-19	09:35	1.01	0.81	173	SCI
HD 161096	PAH2	0	9	2007-04-19	09:46	1.20	0.82	110	CAL
HD 161096	SIC	0	9	2007-04-19	09:49	1.21	0.84	109	CAL
HD 161096	PAH2_2	0	9	2007-04-19	09:52	1.22	0.92	110	CAL
Hen31110	SIC	0	30	2007-04-22	06:20	1.16	1.08	172	SCI
Hen31110	PAH2	0	30	2007-04-22	06:24	1.16	1.07	173	SCI
Hen31110	PAH2_2	0	30	2007-04-22	06:28	1.16	1.14	173	SCI
HD 133550	PAH2	0	9	2007-04-22	06:38	1.04	1.07	110	CAL
HD 133550	SIC	0	9	2007-04-22	06:41	1.04	1.15	109	CAL
HD 133550	PAH2_2	0	9	2007-04-22	06:44	1.05	0.98	110	CAL
Hen31110	SIC	0	30	2007-05-28	05:24	1.20	1.23	171	SCI
Hen31110	PAH2	0	30	2007-05-28	05:28	1.20	1.36	173	SCI
Hen31110	PAH2_2	0	30	2007-05-28	05:32	1.21	1.15	172	SCI
HD 133550	PAH2	0	9	2007-05-28	05:44	1.18	1.07	110	CAL
HD 133550	SIC	0	9	2007-05-28	05:47	1.19	1.13	109	CAL
HD 133550	PAH2_2	0	9	2007-05-28	05:50	1.20	1.15	109	CAL
HD 163376	PAH2	0	9	2007-05-28	06:01	1.05	1.06	110	CAL
HD 163376	SIC	0	9	2007-05-28	06:04	1.05	1.00	109	CAL
HD 163376	PAH2_2	0	9	2007-05-28	06:07	1.05	0.88	109	CAL
AS310	SIC	0	30	2007-05-28	06:28	1.07	1.13	171	SCI
AS310	PAH2	0	30	2007-05-28	06:32	1.06	1.24	173	SCI
AS310	PAH2_2	0	30	2007-05-28	06:37	1.06	1.39	172	SCI
HD 177716	PAH2	0	9	2007-05-28	06:48	1.01	1.33	110	CAL
HD 177716	SIC	0	9	2007-05-28	06:51	1.01	1.26	109	CAL
HD 177716	PAH2_2	0	9	2007-05-28	06:55	1.01	1.25	109	CAL
HD 188603	PAH2	0	9	2007-05-28	08:49	1.01	0.93	110	CAL
HD 188603	SIC	0	9	2007-05-28	08:52	1.01	1.07	109	CAL
HD 188603	PAH2_2	0	9	2007-05-28	08:56	1.01	0.94	109	CAL
HD 177716	SIC	0	9	2007-05-28	10:17	1.28	1.59	109	CAL

Notes. The columns from left to right give the target name, the imaging filter, the orientation (rotating from north to west), the chopper throw, the date and time, the airmass and optical seeing, the integration time and the target category (calibration or science).

Table 5. Log of the entire VISIR *N*-band LR spectroscopy ordered according to observation date.

Target	Setting [μ m]	Orient. [$^{\circ}$]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing [$''$]	Int.time [s]	Category
HD 32887	8.5	0	8	2007-01-06	05:18	1.22	0.94	67	CAL
HD 32887	9.8	0	8	2007-01-06	05:21	1.23	1.00	73	CAL
HD 32887	11.4	0	8	2007-01-06	05:23	1.25	0.96	73	CAL
HD 32887	12.2	0	8	2007-01-06	05:27	1.26	0.93	75	CAL
LkHa208	8.5	0	8	2007-01-06	05:41	1.62	1.18	291	SCI
LkHa208	9.8	0	8	2007-01-06	05:49	1.66	1.28	318	SCI
LkHa208	11.4	0	8	2007-01-06	05:57	1.71	1.39	318	SCI
LkHa208	12.2	0	8	2007-01-06	06:05	1.76	1.32	327	SCI
HD 42995	8.5	0	8	2007-01-06	06:24	1.97	1.37	67	CAL
HD 42995	9.8	0	8	2007-01-06	06:26	2.00	1.40	73	CAL
HD 42995	11.4	0	8	2007-01-06	06:29	2.02	1.45	73	CAL
HD 42995	12.2	0	8	2007-01-06	06:32	2.05	1.53	75	CAL
HD 48915	8.5	0	8	2007-01-06	06:51	1.22	1.13	67	CAL
HD 48915	9.8	0	8	2007-01-06	06:54	1.23	1.12	73	CAL
HD 48915	11.4	0	8	2007-01-06	06:56	1.24	1.10	73	CAL
HD 48915	12.2	0	8	2007-01-06	06:59	1.25	1.32	75	CAL
LkHa339	8.5	45	8	2007-01-06	07:20	1.71	1.35	291	SCI
LkHa339	9.8	45	8	2007-01-06	07:27	1.78	1.35	318	SCI
LkHa339	11.4	45	8	2007-01-06	07:35	1.87	1.28	318	SCI
LkHa339	12.2	45	8	2007-01-06	07:43	1.96	1.46	327	SCI
HD 48915	8.5	0	8	2007-01-06	08:08	1.66	1.64	67	CAL
HD 48915	9.8	0	8	2007-01-06	08:11	1.68	1.60	73	CAL
HD 48915	11.4	0	8	2007-01-06	08:14	1.71	1.63	73	CAL
HD 48915	12.2	0	8	2007-01-06	08:17	1.73	1.63	75	CAL
HD 42995	8.5	0	8	2007-01-08	05:12	1.61	0.88	75	CAL
HD 42995	9.8	0	8	2007-01-08	05:15	1.62	0.89	77	CAL
HD 42995	11.4	0	8	2007-01-08	05:18	1.63	0.90	77	CAL
HD 42995	12.2	0	8	2007-01-08	05:21	1.64	0.88	78	CAL
HD 32887	8.5	0	8	2007-01-08	05:52	1.41	0.79	67	CAL
HD 32887	9.8	0	8	2007-01-08	05:55	1.42	0.83	73	CAL
HD 32887	11.4	0	8	2007-01-08	05:57	1.44	0.80	73	CAL
HD 32887	12.2	0	8	2007-01-08	06:01	1.46	0.85	75	CAL
LkHa208	8.5	0	8	2007-01-08	06:21	1.95	0.94	291	SCI
LkHa208	9.8	0	8	2007-01-08	06:29	2.02	0.97	318	SCI
LkHa208	11.4	0	8	2007-01-08	06:37	2.11	0.98	318	SCI
LkHa208	12.2	0	8	2007-01-08	06:45	2.21	1.06	327	SCI
HD 140573	8.5	0	8	2007-07-30	00:11	1.17	1.24	67	CAL
HD 140573	9.8	0	8	2007-07-30	00:13	1.17	1.19	73	CAL
HD 140573	11.4	0	8	2007-07-30	00:16	1.17	1.11	73	CAL
HD 140573	12.2	0	8	2007-07-30	00:19	1.17	1.33	75	CAL
Hen31110	8.5	0	8	2007-07-30	00:43	1.17	1.01	438	SCI
Hen31110	9.8	0	8	2007-07-30	00:54	1.18	1.74	479	SCI
Hen31110	11.4	0	8	2007-07-30	01:05	1.19	1.88	479	SCI
Hen31110	12.2	0	8	2007-07-30	01:16	1.20	1.69	493	SCI
HD 140573	8.5	0	8	2007-07-30	01:35	1.29	1.12	67	CAL
HD 140573	9.8	0	8	2007-07-30	01:37	1.30	2.25	73	CAL
HD 140573	11.4	0	8	2007-07-30	01:40	1.31	1.96	73	CAL
HD 139127	8.5	0	8	2007-07-30	02:24	1.25	1.40	144	CAL
HD 139127	9.8	0	8	2007-07-30	02:28	1.26	1.55	157	CAL
HD 139127	11.4	0	8	2007-07-30	02:33	1.27	1.47	157	CAL
HD 139127	12.2	0	8	2007-07-30	02:37	1.29	1.46	162	CAL
HD 167618	8.5	0	8	2007-09-10	00:09	1.03	0.74	67	CAL
HD 167618	9.8	0	8	2007-09-10	00:12	1.03	0.71	73	CAL
HD 167618	11.4	0	8	2007-09-10	00:15	1.03	0.69	73	CAL
HD 167618	12.2	0	8	2007-09-10	00:18	1.03	0.67	75	CAL
AS310	8.5	179	30	2007-09-10	00:45	1.09	0.64	438	SCI
AS310	9.8	179	30	2007-09-10	00:57	1.10	0.66	479	SCI
AS310	11.4	179	30	2007-09-10	01:08	1.12	0.72	479	SCI
AS310	12.2	179	30	2007-09-10	01:20	1.14	0.72	493	SCI
HD 167618	8.5	0	8	2007-09-10	01:40	1.13	0.72	67	CAL
HD 167618	9.8	0	8	2007-09-10	01:43	1.14	0.71	73	CAL
HD 167618	11.4	0	8	2007-09-10	01:46	1.14	0.70	73	CAL
HD 167618	12.2	0	8	2007-09-10	01:49	1.15	0.78	75	CAL
HD 200914	8.5	0	8	2007-09-10	02:04	1.01	0.56	144	CAL
HD 200914	9.8	0	8	2007-09-10	02:09	1.00	0.57	157	CAL
HD 200914	11.4	0	8	2007-09-10	02:13	1.00	0.54	157	CAL

Table 5. continued.

Target	Setting [μ m]	Orient. [$^{\circ}$]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing [$''$]	Int.time [s]	Category
HD 200914	12.2	0	8	2007-09-10	02:18	1.00	0.57	162	CAL
HD 169916	8.5	0	8	2007-09-10	23:18	1.01	0.85	144	CAL
HD 169916	9.8	0	8	2007-09-10	23:24	1.01	0.80	157	CAL
HD 169916	11.4	0	8	2007-09-10	23:28	1.00	0.86	157	CAL
HD 169916	12.2	0	8	2007-09-10	23:33	1.00	0.82	162	CAL
HD 167618	8.5	0	8	2007-09-10	23:50	1.02	0.60	67	CAL
HD 167618	9.8	0	8	2007-09-10	23:53	1.02	0.42	73	CAL
HD 167618	11.4	0	8	2007-09-10	23:56	1.02	0.40	73	CAL
HD 167618	12.2	0	8	2007-09-10	23:59	1.03	0.62	75	CAL
MWC297	8.5	0	8	2007-09-11	00:15	1.08	0.84	291	SCI
MWC297	9.8	0	8	2007-09-11	00:22	1.08	0.89	318	SCI
MWC297	11.4	0	8	2007-09-11	00:30	1.09	0.89	318	SCI
MWC297	12.2	0	8	2007-09-11	00:38	1.10	0.84	327	SCI
HD 168454	8.5	0	8	2007-09-11	01:09	1.06	0.88	67	CAL
HD 168454	9.8	0	8	2007-09-11	01:12	1.07	0.83	73	CAL
HD 168454	11.4	0	8	2007-09-11	01:15	1.07	0.89	73	CAL
HD 168454	12.2	0	8	2007-09-11	01:18	1.08	0.79	75	CAL
HD 177716	8.5	0	8	2007-09-11	23:21	1.03	0.66	144	CAL
HD 177716	9.8	0	8	2007-09-11	23:26	1.03	0.62	157	CAL
HD 177716	11.4	0	8	2007-09-11	23:31	1.02	0.57	157	CAL
HD 177716	12.2	0	8	2007-09-11	23:35	1.02	0.60	162	CAL
HD 167618	8.5	0	8	2007-09-11	23:52	1.02	0.67	67	CAL
HD 167618	9.8	0	8	2007-09-11	23:55	1.03	0.61	73	CAL
HD 167618	11.4	0	8	2007-09-11	23:58	1.03	0.62	73	CAL
HD 167618	12.2	0	8	2007-09-12	00:01	1.03	0.64	75	CAL
NGC6611494	8.5	0	8	2007-09-12	00:15	1.03	0.67	291	SCI
NGC6611494	9.8	0	8	2007-09-12	00:23	1.04	0.71	318	SCI
NGC6611494	11.4	0	8	2007-09-12	00:31	1.05	0.76	318	SCI
NGC6611494	12.2	0	8	2007-09-12	00:39	1.06	0.83	327	SCI
HD 168454	8.5	0	8	2007-09-12	00:56	1.05	0.87	67	CAL
HD 168454	9.8	0	8	2007-09-12	00:59	1.05	0.87	73	CAL
HD 168454	11.4	0	8	2007-09-12	01:02	1.06	0.79	73	CAL
HD 168454	12.2	0	8	2007-09-12	01:06	1.06	0.85	75	CAL
HD 165135	8.5	0	8	2007-09-13	00:17	1.03	0.73	67	CAL
HD 165135	9.8	0	8	2007-09-13	00:20	1.03	0.71	73	CAL
HD 165135	11.4	0	8	2007-09-13	00:22	1.04	0.69	73	CAL
HD 165135	12.2	0	8	2007-09-13	00:26	1.04	0.69	75	CAL
PDS477	8.5	0	8	2007-09-13	00:45	1.09	0.67	291	SCI
PDS477	9.8	0	8	2007-09-13	00:53	1.10	0.67	318	SCI
PDS477	11.4	0	8	2007-09-13	01:00	1.12	0.73	318	SCI
PDS477	12.2	0	8	2007-09-13	01:09	1.14	0.77	327	SCI
HD 169916	8.5	0	8	2007-09-13	01:26	1.09	0.72	67	CAL
HD 169916	9.8	0	8	2007-09-13	01:29	1.10	0.74	73	CAL
HD 169916	11.4	0	8	2007-09-13	01:32	1.10	0.72	73	CAL
HD 169916	12.2	0	8	2007-09-13	01:35	1.11	0.72	75	CAL
HD 200914	8.5	0	8	2007-09-13	01:51	1.01	0.76	144	CAL
HD 200914	9.8	0	8	2007-09-13	01:56	1.00	0.77	157	CAL
HD 200914	11.4	0	8	2007-09-13	02:01	1.00	0.72	157	CAL
HD 200914	12.2	0	8	2007-09-13	02:05	1.00	0.74	162	CAL
HD 140573	8.5	0	8	2007-09-13	23:40	1.59	0.98	67	CAL
HD 140573	9.8	0	8	2007-09-13	23:43	1.61	1.00	73	CAL
HD 140573	11.4	0	8	2007-09-13	23:46	1.63	0.99	73	CAL
HD 140573	12.2	0	8	2007-09-13	23:50	1.65	1.21	75	CAL
Hen31110	8.5	0	8	2007-09-14	00:03	1.42	1.10	438	SCI
Hen31110	9.8	0	8	2007-09-14	00:15	1.46	1.09	479	SCI
Hen31110	11.4	0	8	2007-09-14	00:26	1.50	1.12	479	SCI
Hen31110	12.2	0	8	2007-09-14	00:38	1.55	1.16	493	SCI
HD 140573	8.5	0	8	2007-09-14	00:56	2.50	1.14	67	CAL
HD 140573	9.8	0	8	2007-09-14	00:59	2.56	1.10	73	CAL
HD 140573	11.4	0	8	2007-09-14	01:02	2.64	1.23	73	CAL
HD 140573	12.2	0	8	2007-09-14	01:05	2.71	1.10	75	CAL
HD 189319	8.5	0	8	2007-09-14	01:29	1.40	1.11	144	CAL
HD 189319	9.8	0	8	2007-09-14	01:34	1.40	1.03	157	CAL
HD 189319	11.4	0	8	2007-09-14	01:39	1.41	1.09	157	CAL
HD 189319	12.2	0	8	2007-09-14	01:44	1.41	1.07	162	CAL
HD 183799	8.5	0	8	2007-09-14	02:06	1.06	0.66	67	CAL

Table 5. continued.

Target	Setting [μ m]	Orient. [$^{\circ}$]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing [$''$]	Int.time [s]	Category
HD 183799	9.8	0	8	2007-09-14	02:09	1.06	0.66	73	CAL
HD 183799	11.4	0	8	2007-09-14	02:12	1.07	0.79	73	CAL
HD 183799	12.2	0	8	2007-09-14	02:15	1.07	0.77	75	CAL
PDS543	8.5	30	8	2007-09-14	02:28	1.44	0.98	291	SCI
PDS543	9.8	30	8	2007-09-14	02:36	1.48	1.07	318	SCI
PDS543	11.4	30	8	2007-09-14	02:43	1.53	1.05	318	SCI
PDS543	12.2	30	8	2007-09-14	02:51	1.58	1.10	327	SCI
HD 183799	8.5	0	8	2007-09-14	03:07	1.19	0.89	67	CAL
HD 183799	9.8	0	8	2007-09-14	03:10	1.19	0.80	73	CAL
HD 183799	11.4	0	8	2007-09-14	03:12	1.20	0.80	73	CAL
HD 183799	12.2	0	8	2007-09-14	03:16	1.21	0.82	75	CAL
HD 8512	8.5	0	8	2007-09-14	03:30	1.45	1.00	144	CAL
HD 8512	9.8	0	8	2007-09-14	03:35	1.42	1.11	157	CAL
HD 8512	11.4	0	8	2007-09-14	03:39	1.40	1.09	157	CAL
HD 8512	12.2	0	8	2007-09-14	03:44	1.37	1.05	162	CAL
HD 146051	8.5	0	8	2007-09-14	23:38	1.29	0.86	67	CAL
HD 146051	9.8	0	8	2007-09-14	23:41	1.30	0.74	73	CAL
HD 146051	11.4	0	8	2007-09-14	23:43	1.31	0.78	73	CAL
HD 146051	12.2	0	8	2007-09-14	23:47	1.32	0.90	75	CAL
V921Sco	8.5	20	8	2007-09-15	00:00	1.16	1.02	291	SCI
V921Sco	9.8	20	8	2007-09-15	00:08	1.17	1.01	318	SCI
V921Sco	11.4	20	8	2007-09-15	00:15	1.19	0.98	318	SCI
V921Sco	12.2	20	8	2007-09-15	00:24	1.21	0.97	327	SCI
HD 152786	8.5	0	8	2007-09-15	00:39	1.35	1.51	67	CAL
HD 152786	9.8	0	8	2007-09-15	00:42	1.35	1.40	73	CAL
HD 152786	11.4	0	8	2007-09-15	00:45	1.36	1.49	73	CAL
HD 152786	12.2	0	8	2007-09-15	00:48	1.37	1.33	75	CAL
HD 152161	8.5	0	8	2007-09-18	01:01	1.38	0.91	67	CAL
HD 152161	9.8	0	8	2007-09-18	01:04	1.39	0.91	73	CAL
HD 152161	11.4	0	8	2007-09-18	01:06	1.40	0.91	73	CAL
HD 152161	12.2	0	8	2007-09-18	01:10	1.41	0.75	75	CAL
MWC878	8.5	10	8	2007-09-18	01:22	1.33	0.80	291	SCI
MWC878	9.8	10	8	2007-09-18	01:30	1.36	0.80	318	SCI
MWC878	11.4	10	8	2007-09-18	01:37	1.40	0.39	318	SCI
MWC878	12.2	10	8	2007-09-18	01:45	1.44	0.39	327	SCI
HD 168454	8.5	0	8	2007-09-18	02:00	1.25	1.25	67	CAL
HD 168454	9.8	0	8	2007-09-18	02:03	1.26	1.28	73	CAL
HD 168454	11.4	0	8	2007-09-18	02:06	1.27	1.32	73	CAL
HD 168454	12.2	0	8	2007-09-18	02:10	1.28	1.31	75	CAL
HD 33684	8.5	0	8	2007-12-19	03:13	1.29	1.01	70	CAL
HD 33684	9.8	0	8	2007-12-19	03:16	1.29	1.06	77	CAL
HD 33684	11.4	0	8	2007-12-19	03:19	1.29	1.15	77	CAL
HD 33684	12.2	0	8	2007-12-19	03:22	1.29	1.08	79	CAL
MWC789	8.5	75	8	2007-12-19	03:37	1.41	1.11	294	SCI
MWC789	9.8	75	8	2007-12-19	03:45	1.39	1.15	322	SCI
MWC789	11.4	75	8	2007-12-19	03:52	1.38	1.09	322	SCI
MWC789	12.2	75	8	2007-12-19	04:00	1.36	1.18	331	SCI
HD 32887	8.5	0	8	2007-12-19	04:18	1.00	0.72	70	CAL
HD 32887	9.8	0	8	2007-12-19	04:21	1.01	0.74	77	CAL
HD 32887	11.4	0	8	2007-12-19	04:24	1.01	0.76	77	CAL
HD 32887	12.2	0	8	2007-12-19	04:27	1.01	0.81	79	CAL
HD 33684	8.5	0	8	2007-12-19	04:43	1.29	1.10	70	CAL
HD 33684	9.8	0	8	2007-12-19	04:46	1.30	1.10	77	CAL
HD 33684	11.4	0	8	2007-12-19	04:49	1.30	0.99	77	CAL
HD 33684	12.2	0	8	2007-12-19	04:53	1.30	1.02	79	CAL
MWC137	8.5	105	8	2007-12-19	05:06	1.30	0.91	294	SCI
MWC137	9.8	105	8	2007-12-19	05:14	1.30	0.86	322	SCI
MWC137	11.4	105	8	2007-12-19	05:22	1.31	0.87	322	SCI
MWC137	12.2	105	8	2007-12-19	05:30	1.31	0.89	331	SCI
HD 32887	8.5	0	8	2007-12-19	05:48	1.11	0.81	70	CAL
HD 32887	9.8	0	8	2007-12-19	05:51	1.12	0.82	77	CAL
HD 32887	11.4	0	8	2007-12-19	05:54	1.12	0.78	77	CAL
HD 32887	12.2	0	8	2007-12-19	05:57	1.13	0.78	79	CAL
HD 32887	8.5	0	14	2007-12-21	02:41	1.04	0.71	70	CAL
HD 32887	9.8	0	14	2007-12-21	02:44	1.03	0.71	77	CAL
HD 32887	11.4	0	14	2007-12-21	02:47	1.03	0.66	77	CAL

Table 5. continued.

Target	Setting [μ m]	Orient. [$^{\circ}$]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing [$''$]	Int.time [s]	Category
HD 32887	12.2	0	14	2007-12-21	02:50	1.03	0.62	79	CAL
PDS204	8.5	30	14	2007-12-21	03:03	1.66	0.95	294	SCI
PDS204	9.8	30	14	2007-12-21	03:11	1.63	0.98	322	SCI
PDS204	11.4	30	14	2007-12-21	03:19	1.60	1.05	322	SCI
PDS204	12.2	30	14	2007-12-21	03:27	1.58	0.99	331	SCI
HD 42995	8.5	0	14	2007-12-21	03:45	1.56	1.16	70	CAL
HD 42995	9.8	0	14	2007-12-21	03:48	1.56	1.11	77	CAL
HD 42995	11.4	0	14	2007-12-21	03:51	1.55	1.07	77	CAL
HD 42995	12.2	0	14	2007-12-21	03:54	1.54	1.07	79	CAL
HD 54605	8.5	0	8	2007-12-21	06:35	1.02	0.68	70	CAL
HD 54605	9.8	0	8	2007-12-21	06:38	1.02	0.64	77	CAL
HD 54605	11.4	0	8	2007-12-21	06:41	1.02	0.76	77	CAL
HD 54605	12.2	0	8	2007-12-21	06:44	1.02	0.64	79	CAL
PDS27	8.5	0	8	2007-12-21	06:56	1.03	0.76	294	SCI
PDS27	9.8	0	8	2007-12-21	07:04	1.04	0.77	322	SCI
PDS27	11.4	0	8	2007-12-21	07:12	1.05	0.76	322	SCI
PDS27	12.2	0	8	2007-12-21	07:20	1.06	0.72	331	SCI
HD 54605	8.5	0	8	2007-12-21	07:35	1.09	0.63	70	CAL
HD 54605	9.8	0	8	2007-12-21	07:38	1.10	0.65	77	CAL
HD 54605	11.4	0	8	2007-12-21	07:41	1.10	0.72	77	CAL
HD 54605	12.2	0	8	2007-12-21	07:44	1.11	0.76	79	CAL
HD 81797	8.5	0	8	2007-12-22	07:43	1.04	0.63	70	CAL
HD 81797	9.8	0	8	2007-12-22	07:46	1.04	0.63	77	CAL
HD 81797	11.4	0	8	2007-12-22	07:49	1.04	0.65	77	CAL
HD 81797	12.2	0	8	2007-12-22	07:52	1.04	0.63	79	CAL
Hen3331	8.5	0	8	2007-12-22	08:09	1.24	0.85	294	SCI
Hen3331	9.8	0	8	2007-12-22	08:17	1.24	0.83	322	SCI
Hen3331	11.4	0	8	2007-12-22	08:25	1.24	0.85	322	SCI
Hen3331	12.2	0	8	2007-12-22	08:33	1.24	0.85	331	SCI
HD 89388	8.5	0	8	2007-12-22	08:48	1.25	0.77	70	CAL
HD 89388	9.8	0	8	2007-12-22	08:51	1.25	0.81	77	CAL
HD 89388	11.4	0	8	2007-12-22	08:54	1.25	0.83	77	CAL
HD 89388	12.2	0	8	2007-12-22	08:57	1.25	0.82	79	CAL
HD 45348	8.5	0	8	2007-12-23	05:48	1.15	0.78	70	CAL
HD 45348	9.8	0	8	2007-12-23	05:52	1.15	0.73	77	CAL
HD 45348	11.4	0	8	2007-12-23	05:55	1.15	0.74	77	CAL
HD 45348	12.2	0	8	2007-12-23	05:58	1.16	0.74	79	CAL
RMon	8.5	0	8	2007-12-23	06:10	1.24	0.88	294	SCI
RMon	9.8	0	8	2007-12-23	06:18	1.25	1.02	322	SCI
RMon	11.4	0	8	2007-12-23	06:25	1.27	1.01	322	SCI
RMon	12.2	0	8	2007-12-23	06:33	1.28	1.34	331	SCI
HD 54605	8.5	0	8	2007-12-23	06:48	1.03	0.76	70	CAL
HD 54605	9.8	0	8	2007-12-23	06:51	1.04	0.78	77	CAL
HD 54605	11.4	0	8	2007-12-23	06:54	1.04	0.84	77	CAL
HD 54605	12.2	0	8	2007-12-23	06:57	1.04	0.73	79	CAL
HD 45348	8.5	0	8	2008-02-24	03:01	1.26	1.27	70	CAL
HD 45348	9.8	0	8	2008-02-24	03:05	1.26	0.91	77	CAL
HD 45348	11.4	0	8	2008-02-24	03:08	1.27	0.61	77	CAL
HD 45348	12.2	0	8	2008-02-24	03:11	1.28	0.67	79	CAL
LkHa215	8.5	0	8	2008-02-24	03:24	1.55	1.41	294	SCI
LkHa215	9.8	0	8	2008-02-24	03:32	1.60	1.54	322	SCI
LkHa215	11.4	0	8	2008-02-24	03:40	1.65	1.57	322	SCI
LkHa215	12.2	0	8	2008-02-24	03:48	1.71	1.51	331	SCI
HD 48915	8.5	0	8	2008-02-25	00:37	1.02	1.16	70	CAL
HD 48915	9.8	0	8	2008-02-25	00:40	1.02	1.16	77	CAL
HD 48915	11.4	0	8	2008-02-25	00:43	1.01	1.01	77	CAL
HD 48915	12.2	0	8	2008-02-25	00:47	1.01	1.01	79	CAL
MWC147	8.5	105	8	2008-02-25	01:00	1.22	1.23	294	SCI
MWC147	9.8	105	8	2008-02-25	01:08	1.22	1.23	322	SCI
MWC147	11.4	105	8	2008-02-25	01:16	1.23	1.23	322	SCI
MWC147	12.2	105	8	2008-02-25	01:24	1.23	1.23	331	SCI
HD 45348	8.5	0	8	2008-02-25	01:41	1.15	0.56	70	CAL
HD 45348	9.8	0	8	2008-02-25	01:44	1.16	0.50	77	CAL
HD 45348	11.4	0	8	2008-02-25	01:47	1.16	0.61	77	CAL
HD 45348	12.2	0	8	2008-02-25	01:50	1.16	1.09	79	CAL
HD 112142	8.5	0	8	2008-02-25	05:19	1.17	1.30	70	CAL

Table 5. continued.

Target	Setting [μm]	Orient. [$^\circ$]	Chop	Date [y-m-d]	Time [h:m]	Airmass	Seeing [$''$]	Int.time [s]	Category
HD 112142	9.8	0	8	2008-02-25	05:22	1.17	1.21	77	CAL
HD 112142	11.4	0	8	2008-02-25	05:25	1.16	1.24	77	CAL
HD 112142	12.2	0	8	2008-02-25	05:28	1.15	1.24	79	CAL
Hen3847	8.5	5	8	2008-02-25	05:42	1.17	1.17	294	SCI
Hen3847	9.8	5	8	2008-02-25	05:50	1.16	1.22	322	SCI
Hen3847	11.4	5	8	2008-02-25	05:58	1.15	1.12	322	SCI
Hen3847	12.2	5	8	2008-02-25	06:06	1.14	1.12	331	SCI
HD 112142	8.5	0	8	2008-02-25	06:21	1.06	1.92	70	CAL
HD 112142	9.8	0	8	2008-02-25	06:24	1.06	4.37	77	CAL
HD 112142	11.4	0	8	2008-02-25	06:27	1.06	4.38	77	CAL
HD 112142	12.2	0	8	2008-02-25	06:30	1.06	3.09	79	CAL

Notes. The columns from left to right give the target name, the wavelength setting, the orientation of the slit (rotating from north to west), the chopper throw, the date and time, the airmass and optical seeing, the integration time and the target category (calibration or science). The slit-width was kept at $0.4''$ throughout all observations.