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AMBER/VLTI Snapshot Survey on Circumstellar Environments

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Abstract. OHANA is an interferometric snapshot survey of the gaseous circumstellar environments of hot stars, carried out by the VLTI group at the Paranal observatory. It aims to characterize the mass-loss dynamics (winds/disks) at unexplored spatial scales for many stars. The survey employs the unique combination of AMBER's high spectral resolution with the unmatched spatial resolution provided by the VLTI. Because of the spatially unresolved central OBA-type star, with roughly neutral colour terms, their gaseous environments are among the easiest objects to be observed with AMBER, yet the extent and kinematics of the line emission regions are of high astrophysical interest.

Keywords. stars: winds, outflows, circumstellar matter

1. Introduction

The **O**bservatory survey at **H**igh **AN**gular resolution of **A**ctive OB stars (OHANA) combines high spectral with high spatial resolution across the Brγ and He Iλ2.056 lines to characterize the dynamics of winds and disks. It is carried out by the VLTI group at the Paranal observatory with the three-beam combining instrument AMBER (Petrov *et al.* 2007). The survey was designed to make use of the observing time not requested by other programs, usually due to bad weather or unsuitable local sidereal time slots.

2. Observations and Data Reduction

The survey targets consist of twelve bright Be stars, thirteen O and B type supergiants, and one interacting binary (see Table 1). Almost 300 observations were obtained. By design, namely targeting quantities relative to the adjacent continuum, no calibrators were observed. However, in some nights calibrators, taken for technical purpose or other programs using the same setup, are available. These have been added to the database.

Basic data reduction was performed with amdlib, v3.0.6 (Tatulli *et al.* 2007; Chelli *et al.* 2009), and then processed further with idl. In particular:

• The pixel shifts between the spectral channels were a matter of concern, and seem not to be entirely stable. Whether this is a real effect or a consequence of noise affecting the determination of the shift is under investigation.

• Since the program aims for relative quantities, which do not suffer from degradation of absolute visibility, 100% of the frames were selected for display in this work. However, the final reduction includes several lower selection ratios as well.

• In the case of continuous observations of more than 30 minutes, (u, v) points were merged into 30 minute bins.

Table 1. Observed targets, spectral types, and data obtained. For each spectral line, the number of observations on the **s**mall, **i**ntermediate, and **l**arge telescope configurations (s–i–l) are given.

Target	**Sp. type**	**Brγ** s–i–l	**He**Iλ**2.056** s–i–l	**Target**	**Sp. type**	**Brγ** s–i–l	**He**Iλ**2.056** s–i–l
	Be Stars				**OBA Supergiants**		
μ Cen	B2 Vnpe	2–5–3	0–1–0	η Car	LBV	22–16–5	3–1–0
χ Oph	B2 Vne	0–0–1	0–0–0	HR Car	LBV	4–4–1	2–0–0
ζ Tau	B2 IVe-sh	2–1–0	1–0–0	ζ Pup	O4 If	4–6–1	1–2–2
δ Cen	B2 IVne	3–5–2	1–1–1	ι Ori	O9 III	1–2–0	1–0–0
ϵ Cap	B3 Ve-sh	1–5–4	0–2–0	ζ Ori	O9.7 Iab	2–1–2	1–0–1
β^1 Mon A	B3 Ve	6–8–0	2–1–0	ϵ Ori	B0 Iab	1–1–0	0–0–0
β^1 Mon B	B3 ne	2–1–0	0–0–0	κ Ori	B0 Iab	3–2–0	2–0–0
β^1 Mon C	B3 e	2–1–0	0–0–0	ζ^1 Sco	B0.5 Ia+	0–1–3	0–0–1
P Car	B4 Vne	6–5–2	2–3–1	γ Ara	B1 Ib	0–1–0	0–1–0
β Psc	B6 Ve	1–4–4	0–2–0	HR 6142	B1 Ia	0–0–1	0–0–1
η Tau	B7 IIIe	0–0–0	1–0–0	ϵ CMa	B2 Iab	4–3–1	1–1–1
Electra	B8 IIIe	0–0–0	1–0–0	HD 53 138	B3 Ia	11–16–3	2–5–1
	Interacting Binary			V533 Car	A6 Iae	3–5–2	1–1–1
SS Lep	A1 V + M6 II	7–1–2	1–1–2				

• Intensity spectra were extracted, and the absolute wavelength scale corrected using telluric lines. The flux continuum was normalized to unity.

• Visibilities in the continuum were normalized to unity, phases in the continuum to zero. If calibrators were taken, these were used to check for and eventually remove instrumental ripples.

• RMS in the continuum was measured for each quantity to estimate data quality.

The raw data have become public immediately, and the results of the final reduction of the Brγ observations will be made public as soon as they are complete. The reduction of the HeIλ2.056 observations is pending.

3. Data Description and First Impressions

Due to the snapshot/backup/filler nature of the program, the data quality is inhomogeneous. Typical values for a good data set are an uncertainty of the visibility (normalized to unity) of about ± 0.05, and of the phase $\pm 2°$, at a SNR of the combined spectrum of above 100. Selected data sets of the target stars are shown in Figs. 1 and 2. For each of the four targets, four baselines are shown, taken from two observations. The uppermost panels for each target show the flux spectra, then subpanels a-d show visibility and phase (upper and lower resp. profiles), while the centered panel show the (u, v) plane covered by the four baselines shown.

3.1. *Be Stars*

Visual inspection of the Be star observations shows them to be compatible with the canonical picture, namely a circumstellar decretion disk. The targets span all inclinations (equatorial to pole-on) and spectral subtypes. For some of the brighter stars the disk is already well resolved in the intermediate configuration (typical baseline lengths 30–70m), and overly resolved in the large configuration (typical baseline lengths 80–130m) Data for β^1 Mon and μ Cen are shown in Fig. 1. μ Cen shows a broad shallow ramp-type wing in the line, which is reflected in the phase. This may be the signature of freshly ejected material closer to the star than the bulk of the disk.

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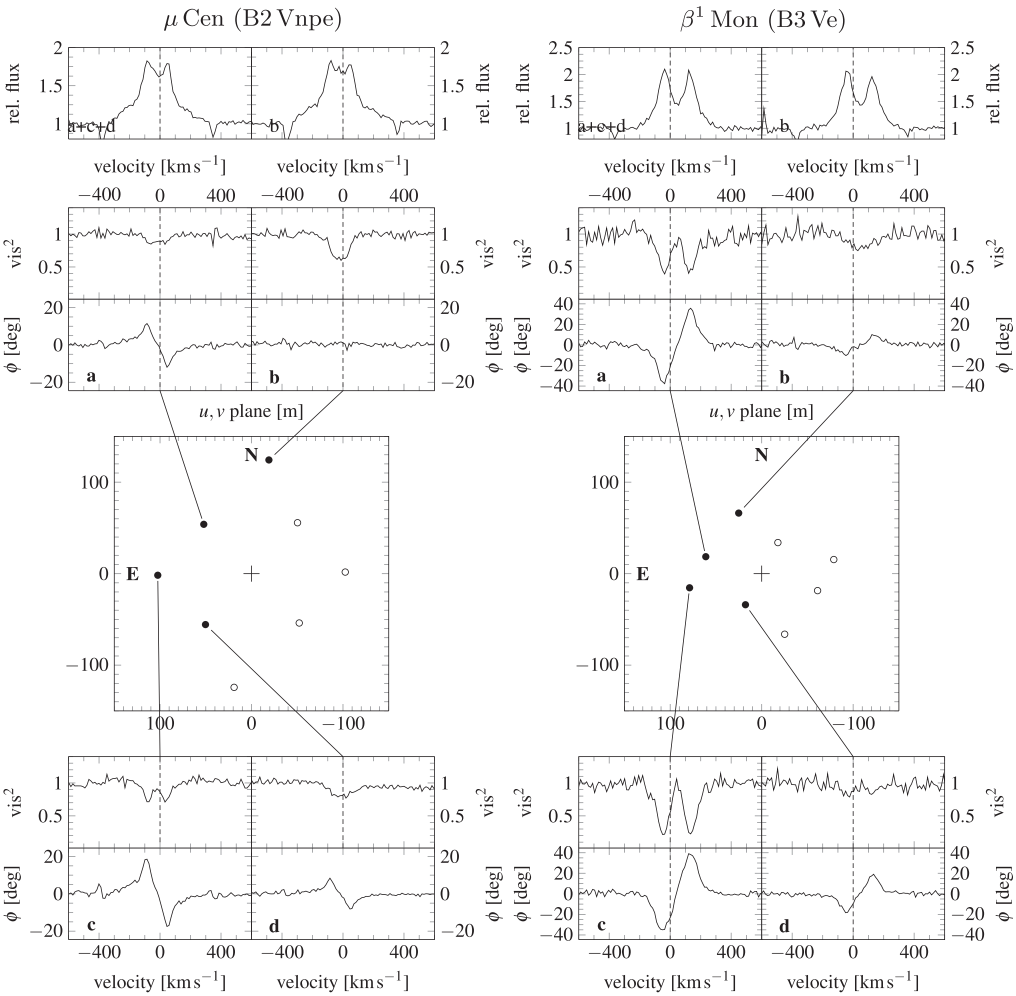

Figure 1. Example of OHANA data for the Be stars μ Cen and β^1 Mon.

3.2. *OB Supergiants*

The OBA supergiants can be divided into three distinct sets, namely LBVs and the remaining ones along the wind bi-stability at about $T_{\rm eff} = 22\,000$ K. For the LBVs η Car and HR Car, dedicated contributions to this volume are presented by Mehner *et al.* and Rivinius *et al.* The O- and early B-supergiants do not show any obvious signature in visibility or phase, meaning their winds are too small to detect. In turn, the later B- and A-type supergiants do show such signatures in visibility, but again very little in phase. This is obvious for the hypergiant ζ^1 Sco, indicating an extended, but largely symmetric wind (Fig. 2, left). For HD 53 138 this is less obvious in Fig. 2, right, but comparison with calibrator data shows the visibility signature to be real, not instrumental. For HD 53 138 spectral emission variability goes together with a changing visibility and phase signature, which may indicate a variable, asymmetric wind. Further analysis of the data at hand may provide constraints on the size and clumping of these winds, while further observations may be able to trace variability, in particular for the slower winds with flow times of up to several weeks.

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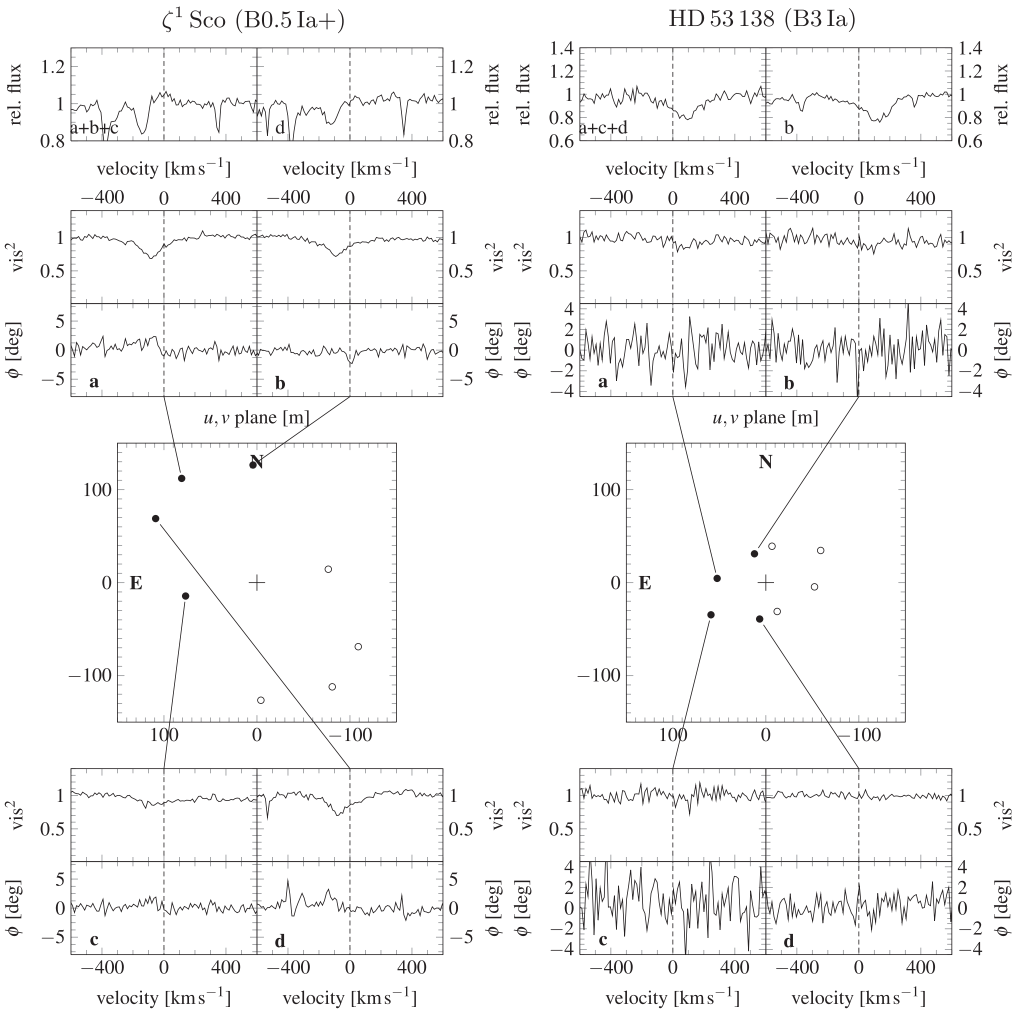

Figure 2. Example of OHANA data for the B-type supergiants ζ^1 Sco and HD 53 138.

3.3. *Interacting Binaries*

The only observed interacting binary was SS Lep, with barely any interferometric signature. Small wiggles seen in the visibility of some longer baselines need to be verified.

4. Conclusions

The OHANA survey provided interferometric data of the circumstellar environments of Be stars and OBA supergiants. The raw data is publicly available, the reduced data will become so as soon as the final reduction has passed quality control tests. The reduced data will be made available from `http://activebstars.iag.usp.br/index.php/34-ohana`.

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