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# THE NATURE OF STARS WITH THE B[E] PHENOMENON THROUGH INTERFEROMETRIC EYES

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RESUMEN

Se sabe que las estrellas que presentan el fenómeno B[e] forman un grupo heterogéneo. Este grupo lo componen objetos en diversas etapas evolutivas, como las estrellas evolucionadas de alta y baja masa, las estrellas de pre-secuencia principal de masa intermedia y los objetos simbióticos. Sin embargo, más de 50% de las estrellas B[e] no tienen un estadío evolutivo bien conocido, y éstas forman el grupo de las estrellas B[e] no clasificadas. La interferometría de alta resolución angular es ciertamente una herramienta importante para responder a cuestiones relacionadas con la geometría circunestelar de estos objetos. En este trabajo, presentamos los resultados relacionados con siete objetos, basados en observaciones realizadas con VLTI/MIDI, VLTI/AMBER y CHARA/VEGA.

ABSTRACT

Stars that present the B[e] phenomenon are known to form a heterogeneous group. This group is composed by objects in different evolutionary stages, like high- and low-mass evolved stars, intermediate-mass pre-main sequence stars and symbiotic objects. However, for more than 50% of the confirmed B[e] stars the evolutionary stage is still unknown, so that they are gathered in the group of the unclassified B[e] stars. High-angular resolution interferometry is certainly an important tool to answer questions related to the circumstellar geometry of these objects. In this work, we present the results related to seven objects, based on observations from VLTI/MIDI, VLTI/AMBER and CHARA/VEGA.

*Key Words:* stars: circumstellar matter — stars: mass loss — techniques: interferometric



## 1. INTERFEROMETRY AND STARS WITH THE B[E] PHENOMENON

The distribution of the circumstellar gas and dust has a key role to explain the formation of the B[e] phenomenon in the different classes of B[e] stars already identified (Lamers et al. 1998). In addition, more than 50% of the galactic B[e] stars are not or doubtfully classified. The main reason for this problem is due to the absence of knowledge concerning their physical parameters, especially the distance, and the geometry of their circumstellar matter.

Recently the optical/IR long baseline interferometry, especially with the VLTI and CHARA, has become an important tool to deeply study the circumstellar environment of the brightest B[e] stars. Thanks to the field of view and the high spatial resolution of instruments, like AMBER, MIDI and VEGA, it is possible to have access to information related to circumstellar medium close to the stars, allowing us to obtain sizes, shapes, and orientations, as a function of wavelength in the optical, near and mid-IR ranges.

## 2. OUR SAMPLE

Our group has already studied seven galactic B[e] stars. The data and results obtained for each object, some of them preliminary, are presented here:

- GG Car, CPD°572874 and HD 62623

These three stars are in general considered in the literature, as B[e] supergiants, however this classification needs to be seen with caution, especially due to uncertainties related to their physical parameters.

For CPD°572874, Domiciano de Souza et al. (2007) showed that, based on MIDI data, the dust responsible for the N-band emission is distributed in a structure similar to an equatorial disk. On the other hand, AMBER data show that the near-IR emission comes from a structure not so elongated. These differences support the two-component wind scenario suggested by Zickgraf et al. (1985) for B[e] supergiants.

GG Car is actually a binary system (Hernandez et al. 1981; Gosset et al. 1985), where the main com-

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ponent is probably a B[e] supergiant. From the modeling of visibilities obtained from MIDI, the presence of a dusty disk, seen under an intermediate inclination angle ($50° - 60°$) and assuming a distance for this object around 1 kpc, seems to be confirmed (Carciofi et al., in preparation). In addition, for HD 62623, probably the first galactic A[e] supergiant identified (Bittar et al. 2001), the presence of a dusty stratified disk is also confirmed by the analysis of MIDI data (Meilland et al., in preparation).

- HD 50138 and HD 45677

These two stars are the closest and brightest B[e] stars already identified. Their evolutionary stages are not well known. HD 50138 was classified in the literature either as a classical Be or a pre main-sequence Herbig star, however a binary nature was not discarded. Recently a deep spectroscopic and photometric analysis was performed, confirming that HD 50138 has suffered outbursts and shell-phases, which are responsible by a large mass-loss and slow-down of this star (Borges Fernandes et al. 2009, submitted). The most recent shell-phase took probably place before 2007. MIDI data were obtained in 2007 and the visibilities could be modeled assuming a uniform disk, which the diameter ranges from 27 mas to 37 mas, as a function of the wavelength, from 8 $\mu$m to 12 $\mu$m respectively. More data have just been obtained and are under analysis (Borges Fernandes et al., in preparation).

Though being considered the "prototype" of B[e] stars, the nature of HD 45677 still remains quite uncertain, being considered either as a pre main-sequence Herbig star, or a post-AGB object, or a main-sequence star in a binary system, or simply as an unclassified B[e] star. Monnier et al. (2006), based on data obtained with IOTA, found the presence of a large nonzero closure phase, which was modeled assuming a skewed elliptical model. MIDI data, obtained by us, show the presence of a strong silicate band and they can be modeled assuming an elliptical gaussian disk (major axis of 120 mas and minor axis of 30 mas; Kanaan et al., in preparation).

- HD 87643

This badly understood B[e] star was observed by us in a multi-wavelength and observational campaign, including interferometry (AMBER and MIDI), spectroscopy (ESO/1.52 m/FEROS) and imaging (VLT/NACO and ESO/2.2 m/WFI) data. Based on this analysis, it was possible to obtain more constraints concerning the distance of this object (0.8–1.5 kpc) and the structure of its complex circumstellar nebula. However, the most remarkable result is related to the presence of a cool companion, separated by 34 mas, which was discovered by imaging reconstruction of AMBER data (Millour et al. 2009, submitted). This binary system is embedded in a dense dusty nebula, with angular dimension between 200 and 1000 mas.

- MWC 361

This is the only northern star of our sample. This object is actually a close-binary system (there is a third companion, which is further than 6″), composed by a young early Be star with a resolved disk and by a lower-mass late-type Be companion (Monnier et al. 2006). We have successfully detected fringes, using the shortest baseline for VEGA. These data will provide information concerning the disk characteristics, especially from the H$\alpha$ emitting-region (Borges Fernandes et al., in preparation).

## 3. CONCLUSIONS

Interferometry is the ideal tool to provide information concerning the geometry and inclination of the circumstellar matter of stars with the B[e] phenomenon. These results will certainly contribute for, in a near future, (i) the comprehension of the nature of some unclassified B[e] stars, (ii) the inclusion of the B[e] phenomenon in the evolutionary tracks and (iii) the comprehension of stellar phases that are not well understood yet.

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## DISCUSSION

**Michel Curé:** *Can we obtain the rotation velocity from the interferometric observations?* — Not from our data. In our sample, the projected rotational velocity was derived for just one object, HD 50138, from spectroscopic observations.

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