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The circumstellar environment of the B[e] star GG Car: an interferometric modeling

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Abstract. The research of stars with the B[e] phenomenon is still in its infancy, with several unanswered questions. Physically realistic models that treat the formation and evolution of their complex circumstellar environments are rare. The code HDUST (developed by A. C. Carciofi and J. Bjorkman) is one of the few existing codes that provides a self-consistent treatment of the radiative transfer in a gaseous and dusty circumstellar environment seen around B[e] supergiant stars. In this work we used the HDUST code to study the circumstellar medium of the binary system GG Car, where the primary component is probably an evolved B[e] supergiant. This system also presents a disk (probably circumbinary), which is responsible for the molecular and dusty signatures seen in GG Car spectra. We obtained VLTI/MIDI data on GG Car at eight baselines, which allowed to spatially resolve the gaseous and dusty circumstellar environment. From the interferometric visibilities and SED modeling with HDUST, we confirm the presence of a compact ring, where the hot dust lies. We also show that large grains can reproduce the lack of structure in the SED and visibilities across the silicate band. We conclude the dust condensation site is much closer to the star than previously thought. This result provides stringent constraints on future theories of grain formation and growth around hot stars.

Keywords. stars: emission-line, Be, stars: individual (GG Car), supergiants, techniques: high angular resolution, techniques: interferometric, spectroscopic, photometric

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1. Introduction

The B[e] phenomenon, observed in different classes of stars, is characterized in particular by strong emission lines (permitted and forbidden) and strong IR excess due to hot circumstellar dust (e.g. Lamers *et al.* 1998). Among the stars presenting the B[e] phenomenon, the supergiants (sgB[e] stars) are a challenge to models of stellar evolution (they are not predicted by them) and of dust formation around hot, massive stars. Fast-rotation of the central star and binarity seem to be intimately related to the sgB[e].

In the last decade, optical/IR long-baseline interferometry (OLBI) became an important tool to deeply and directly study the circumstellar environment (CSE) of the brightest B[e] stars. We used the ESO-VLTI/MIDI beam combiner to study the CSE of binary system GG Car, where the primary component is probably a sgB[e] (Marchiano *et al.* 2012; Kraus *et al.* 2013). However, its distance is very uncertain, ranging from 1 to 5 kpc (Borges Fernandes, private comm.; Marchiano *et al.* 2012). Recent works (based on spectropolarimetry, CO emission lines) suggest the presence of a rotating disk-like structure, probably a narrow circumbinary ring (Pereyra *et al.* 2009; Kraus *et al.* 2013).

† Based on observations performed at the European Southern Observatory, Chile under ESO Programs 074.D-0101 and 076.D-0663.

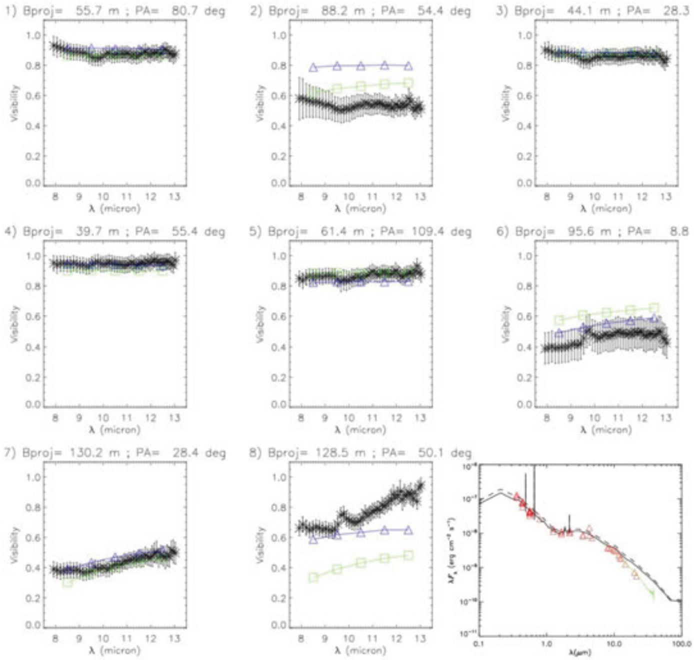

Figure 1. Observed MIDI visibilities and SED (several literature data) measured on GG Car. The model was calculated with the HDUST code (see text for further details).

2. Results

GG Car was observed between Dec. 2004 and Dec. 2005 with MIDI, the mid-IR, two-telescope interferometric beam-combiner of ESO-VLTI. As a preliminary study to interpret the observations we used the grid of HDUST sgB[e] models from Domiciano de Souza & Carciofi (2012). The central star is modeled as a B type star of $T_{\rm eff} \sim 20\,000\,$K, $R \sim 10\,R_{\odot}$, and $L \sim 10^4\,L_{\odot}$. Figure 1 compares the MIDI visibilites and SED with our HDUST model. Our preliminary models can mostly describe the VLTI/MIDI data and SED. However, they are not a perfect representation of the circumstellar environment of GG Car; for example some line profiles (not shown here) are not well reproduced.

As an important result our analysis suggests that, despite of the uncertainty in the distance, the hot-dust site is ring shaped and somewhat compact, with the dust being formed at distances of $\lesssim 100\,R$ (much closer to the star than previously thought). We also find that large grains (sizes from 1 to 50 μm) are required if amorphous silicate are used (as in our models) to reproduce the lack of mid-IR structure in the SED and visibilities.

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