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Catching the Binaries Amongst B[e] Stars

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Abstract. It is surprising to f nd dust around B type stars, as in the case of B[e] stars. These stars exhibit a dense, dusty environment witnessed by their infrared-excess and many emission lines from permitted and forbidden transitions. Given the large uncertainties on their distances, this spectral type gathers many different kind of sources that may harbor a similar circumstellar environment, i.e. a dense dusty disk. At the exception of Young Stellar Objects, in many cases, it is very difficult to understand the origin of such a disk without invoking binarity. We describe current powerful methods, like spectral disentangling, spectro-astrometry and long baseline interferometry, to detect especially close binaries amongst the unclassif ed B[e] stars. The role of binary mergers in the formation of the B[e] phenomenon, especially in supergiants and compact PNe, is also discussed.

1. Introduction

B[e] stars are stars of spectral type B with plenty of emission lines from permitted and especially forbidden transitions in predominantely neutral or low-ionized metals like O I and Fe II. In addition, these stars show strong infrared excess emission due to warm and hot circumstellar dust. Since these spectral characteristics are related purely to the circumstellar medium of these objects, it is obvious that they might be found in stars in quite different evolutionary phases. And indeed, a detailed investigation of the B[e] stars performed by Lamers et al. (1998) revealed that B[e] stars can be pre-main sequence as well as post-main sequence in nature (see Table 1).

Despite the classif cation of B[e] stars according to their evolutionary phases, more than half of all galactic B[e] stars still remain unclassif ed, since the properties of these objects do not f t into any of these classes, nor do objects of this sub-sample show many common characteristics besides the B[e] phenomenon itself. It has thus been speculated that these stars might be binaries and that the circumstellar material, responsible for the B[e] phenomenon seen in these stars, might have been ejected during phases of binary interaction (see, e.g., Kraus & Miroshnichenko 2006). The number of conf rmed bina-

Table 1. B[e] phenomenon in various types of stars. Listed are the different B[e] characteristics and their origin. Only the symbiotics are known to be interacting binaries, while in the other B[e] classes a binary component is not needed (but see Sect. 3). Numbers in parentheses refer to B[e] supergiant candidates (see Kraus 2009). Note that the only known extragalactic B[e] stars are supergiants in the Magellanic Clouds.

	Herbig B[e]	cPNe B[e]	B[e] supergiant	symbiotic B[e]
B-type spectrum	B-type pre-main sequence star	obscured O-type white dwarf	B-type supergiant	obscured hot compact obj.
forbidden emission lines	reflection nebula	PN nebula	high-density non-spherical wind	associated nebula
dust and Balmer lines	pre-main sequence accretion disk	high-density dusty disk	high-density (outflowing ?) disk	accretion disk
number of confirmed binaries	4/9	0/12	0/10 (LMC) 1/4(+2) (SMC) 2/(14) (MW)	all ~ 200

ries is, however, rather small. A step forward to prove this hypothesis might therefore be a detailed search for (especially interacting) binary components in these objects.

2. Search for Binarity - More Problems Than Solutions

The search for binarity in the unclassified B[e] stars is not straightforward. The objects are usually faint, suffering from mostly unknown but large amounts of predominantely circumstellar extinction. In addition, their distances are far from being constrained, hampering proper luminosity determinations.

Some promising tools for finding binary components came up during the past years, and their applicability to B[e] stars and reliability is discussed in the following.

2.1. Spectral Disentangling

Spectral disentangling is a powerful tool for the analysis of composite spectra of eclipsing binary or multiple stars. However, the requirement for proper disentangling is that high-quality spectra are available and cover as much as possible of the orbital period (see Hensberge et al. 2008).

In extremely rare cases composite spectra of B[e] stars have been obtained as in the case of MWC 623 (Zickgraf & Stahl 1989; Polster et al., this volume), which might be a binary with a rather large period (> 14 years). However, in general the method of spectral disentangling is not advisable for finding binary components in B[e] stars, because these stars are embedded in irregularly shaped and highly dynamical circumstellar material, contributing and polluting significantly the photospheric lines. In addition, several B[e] stars have been found to have dynamical atmospheres as well, resulting in irregular line variations, since lines of different elements are formed at different atmospheric depths, delivering a variety of radial velocities (see, e.g., Borges Fernandes et al. 2009). If such kind of lines are further contaminated by emission from dynamical and complex circumstellar material, the method of spectral disentangling can thus most probably be considered as delivering results, which might be rather unsatisfactory or even incorrect.

2.2. Spectroastrometry

A more sophisticated technique in f nding especially close binaries uses spectro-astrometry (Bailey 1998; Porter et al. 2004). This method has been successfully applied to Herbig Ae/Be stars, since it is particularly suited for emission line stars (see, e.g., Baines et al. 2006). The great advantage of spectro-astrometry lies in its ability to detect binary companions that are fainter by up to 6 mag. However, the method is limited to separations larger than 100 mas.

The sample of Baines et al. (2006) contained three unclassif ed B[e] stars: HD 45677, HD 50138, and HD 87643. The f rst two were claimed to be new binary discoveries, while the last one showed a highly complex spectro-astrometry, which, however, was not in agreement with a binary component. HD 87643 was thus discarded by Baines et al. (2006) as a binary system.

2.3. Interferometry and Image Reconstruction

Another tool to discover even closer binaries with separations $\ll$ 100 mas is provided by optical long baseline interferometry. For instance, observing classical Be stars, Meilland et al. (2008) discovered a companion to δ Cen at a separation of 68.7 mas. Long baseline interferometry, nowadays limited to bright stars, additionally allows to resolve small scale structures, constraining the geometry of the circumstellar or circumbinary material (see, e.g., Netolický et al. 2009; Bonneau, this volume).

In addition, Millour et al. (2009) recently applied a new technique of image reconstruction for the VLTI/AMBER observations of the B[e] star HD 87643, based on which they resolved a cool companion at a separation of 34 mas. This method thus seems to be the most powerful one to disentangle companions at angular separation typically larger than 1 mas, i.e. 1-2 AU at 1-2 kpc, with typical periods larger than a few months. Such systems are difficult to detect by classical spectroscopy.

3. Binary Mergers

Table 1 highlights that all classif ed B[e] stars possess a high-density dusty disk. This feature is especially puzzling for compact PNe and luminous supergiants. In addition, detailed investigations on the compact PNe Hen 2-90 revealed a latitude dependent ionization structure of its wind (Kraus et al. 2005), while no evidence for binarity was found (Kraus et al. 2007). Such wind structures are generally observed from rapidly rotating stars. Also, several Magellanic Cloud B[e] supergiants were found to be rapidly rotating (see, e.g., Kraus et al. 2008). Since rapid rotation is not expected for stars in these evolutionary phases, the stars must have been spun up. The most natural cause for a star to spin up is provided by binary merger processes (e.g., Podsiadlowski et al. 2006). Such a scenario seems to be quite plausible, given that about 10 % of all stars are expected to experience a merger process, as suggested by population synthesis models. For compact PNe and supergiants the B[e] phenomenon might therefore be strictly linked to binary merger processes, though a proof of this hypothesis, e.g., in terms of abundance studies, has not been made yet.

4. Conclusions

The B[e] phenomenon in the yet unclassif ed stars has been proposed to be due to binary interaction. However, to test this hypothesis is a challenging task, since the methods of binary identif cation quickly reach their limit of applicability for stars being surrounded by highly complex and highly dynamical material. Therefore, it is quite sobering, how little results have been achieved so far. Using spectro-astrometry two binary systems were detected. The distribution of circumstellar material of a third B[e] star studied was too complex and the separation of its binary component too small to be catched by spectro-astrometry. Instead, this system was resolved by interferometry and image reconstruction techniques.

The discovery of close binaries amongst the unclassif ed B[e] stars is the f rst but most important step towards understanding their nature. The search for indications that interaction has been taking place is the next step to test the hypothesis. This task is challenging, especially with respect to the large number of unclassif ed B[e] stars, but with the advent of the described new techniques our odds are improving.

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