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Binarity among objects with the Be and B[e] phenomena

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Abstract. Many B-type stars exhibit two phenomena that are symbolized Be and B[e]. The former refers to presence of a circumstellar gaseous disk without significant circumstellar dust, while the latter have dust. Although neither phenomenon is fully understood, growing evidence suggests that binarity plays an important role. Recent results on Be and B[e] binaries, along with methods of their discovery, are reviewed.

Key words: Stars: emission-line, Be, B[e] – Stars: binaries: spectroscopic

1. Introduction

Two emission line phenomena, found almost exclusively in stars of spectral type B, are due to large amounts of circumstellar material. These Be and B[e] stars were not expected to be mostly in binary systems, but their estimated binary fractions have steadily grown with time.

The Be phenomenon was discovered at the dawn of astronomical spectroscopy in the middle of the 19th century by visual observing of hydrogen emission lines in the spectrum of γ Cassiopeae (Secchi, 1866). The B[e] phenomenon was discovered 110 years later in the course of an early near-infrared (IR) photometric survey combined with optical spectroscopy. It was defined as the presence of both permitted and forbidden line emission along with a large IR excess due to radiation of circumstellar (CS) dust (Allen & Swings, 1976). Major features of both phenomena are summarized in Table 1.

2. Properties of objects with both phenomena and connections to binary systems

2.1. The Be phenomenon

One of the main features of the Be phenomenon is rapid rotation that may be due to initial fast rotation or to later mass transfer in a binary system. Many B–type stars with broad absorption lines (known as Bn stars) have not been found to exhibit emission lines, thus suggesting that fast rotation alone may not be the only mechanism for the phenomenon creation, especially in strong-lined Be stars. A binary hypothesis as a reason for the phenomenon was first proposed by Kriz & Harmanec (1975) and initially attributed to ongoing transfer of mass and angular momentum to the B–type component. However, this hypothesis was taken with caution because only $\sim$40 binaries were recognized among over 1000 known Be stars by the end of the 20th century (e.g., Gies, 2000; Harmanec, 2001). The advent of high-resolution spectroscopy, including a large contribution from the amateur community collected in the BeSS database (Neiner et al., 2011), allowed to observe Be stars more frequently and sharply increased the number of confirmed Be binaries. Currently 14 out of the brightest 24 Be stars ($V \leq 4$ mag) and 75 out of 237 Be stars with $V \leq 7.5$ mag are known binary systems (Miroshnichenko, 2016). Apparent decrease of the binary fraction toward fainter objects is due to observational selection effect, as fainter stars are not observed as frequently as brighter ones.

The line emission in Be stars is variable at different levels. Some objects show very little variation for decades (e.g., β CMi), while others exhibit periods of strong line emission followed by “normal” star phases, when the emission lines and IR excess disappear completely. Some examples of the latter include π Aqr (Bjorkman et al., 2002), 66 Oph, and ϕ And (see Fig. 1, left panel). Be disks may also reappear unexpectedly in previously known Be stars (e.g., π Aqr, Zharikov et al., 2013) or form around B–type stars for the first time (e.g., δ Sco, Miroshnichenko et al., 2001). It has been suggested that disk formation can be triggered by non-radial pulsations (see Rivinius et al., 2013, for a recent review) or by periastron passages in highly eccentric binaries (δ Sco). The disks are

Table 1. Main features of the Be and B[e] phenomena

Feature	Be	B[e]
Emission lines	Permitted transitions: H I, Fe II except the coolest	Permitted and forbidden transitions: same + Na I
	no forbidden lines	[O I], [Fe II], [N II], [S II] [O III] – B0–B2
IR-excess	free-free + free-bound CS gas	CS gas + dust thermal radiation
Rotation	close to break-up velocity	slower than that of Be stars

typically Keplerian, but the CS gas may both fall back onto the star or move away due to viscosity.

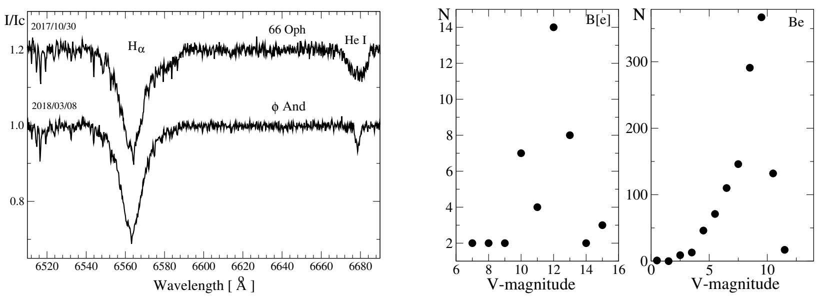

Figure 1. Left panel: Parts of the spectra of two Be stars that lost their disks. The spectra were taken with a 0.81 m telescope of the Three College Observatory in North Carolina, USA, with a spectral resolving power of $R \sim 12,000$. The dates of observation along with the objects names and spectral lines shown are indicated. The intensity is normalized to the local continuum, the wavelength scale is given in Angströms. **Right panel:** Brightness distribution of Galactic Be stars and FS CMa objects with the B[e] phenomenon.

2.2. The B[e] phenomenon

The B[e] phenomenon is present in objects of 4 groups with known nature (pre-main-sequence Herbig Ae/Be stars, a small group of supergiants, symbiotic binaries, and some proto-planetary and planetary nebulae, Lamers et al., 1998). However, half of the originally found 65 objects were not classified, because they either had no reliable luminosity estimates or showed properties of more than one of the groups. Recently Miroshnichenko (2007) suggested that most unclassified objects with the B[e] phenomenon may actually be binary systems that have undergone non-conservative mass transfer, which was responsible for formation of the CS material, including dust. This group was named FS CMa type objects after the prototype object with the B[e] phenomenon (Swings, 2006). The group's SEDs show a lack of cold dust compared to young stars and planetary nebulae and typically very strong emission-line spectra. The group has been expanded several times (Miroshnichenko et al., 2007, 2017) and nearly 20 binary systems have been found among its members by various methods, including five with measured orbital periods. It is harder to reveal their binarity than in Be stars due to a more complicated structure and variability of the CS medium, as well as their lower brightness (see Fig. 1, right panel). However a growing number of their observations, especially at big telescopes (including SALT, CFHT, the 2.1 m telescope of the Observatorio Astronómico Nacional San Pedro Martir, and 2 m Himalayan Chandra Telescope) will eventually result in verifying the binary hypothesis.

3. Conclusions

There is growing evidence that many stars with the Be and B[e] phenomena are binary systems, most of which have undergone mass transfer between the components due to Roche lobe overflow. The number of confirmed Be binaries is steadily growing. The situation with B[e] objects is similar: symbiotic systems are binaries by definition, while most B[e] supergiants and a number of FS CMa objects have been found to be binaries as well. Binarity can be revealed with several methods, which include observing regular radial velocity variations or orbital phase locked intensity variations of double-peaked emission-line profiles (in weak-lined Be stars Zharikov et al., 2013), eclipses, and resolving individual components with interferometry and spectro-astrometry. Spectroscopic methods are still the most successful but require long-term observing campaigns and collaboration between professional and amateur astronomers.

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