Understanding classical Be stars thanks to K2's Field 9

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Context

Classical Be stars are rapidly-rotating pulsating massive stars that host a decretion circumstellar disk. This disk is created from matter ejected by the star through sporadic events. How these ejections occur is not understood yet, but they are most likely related to the very rapid rotation of these stars and to their pulsations. The correlation between pulsations and the ejections of matter was first proposed by Rivinius et al. (2001, A&A 369, 1058) and firmly established by Huat et al. (2009, A&A 506, 95) thanks to CoRoT observations.
CoRoT observed a few bright Be stars and allowed us to progress significantly on this issue. In particular, sub-inertial gravito-inertial (gi) modes (below twice the rotation frequency) have been detected in the early Be star HD 51452 (Neiner et al. 2012, A&A 546A, 47). These modes cannot be excited by the κ mechanism usually invoked for those stars, because HD 51452 is too hot (B0 IVe) to be in the κ-driven g-mode instability strip. Since the observed modes have very low frequency and a short lifetime, we have proposed that they are excited stochastically in the convective core and at its interface with the surrounding radiative envelope.
In addition, low-frequency g modes have been observed with CoRoT in another early Be star, HD 49330, during an outburst (Huat et al. 2009, A&A 506, 95). We propose that these modes are also stochastically excited, as suggested by their short lifetime. Indeed, these modes are only visible during the outburst, while the κ-driven p modes get destabilized at that time. However, in this case, the stochastic modes we observed are probably those excited just below the surface rather than the ones excited in the convective core.
It was not expected that stochastically-excited gi modes could be observed in massive stars (Samadi et al. 2010, Ap&SS 328, 253), although Shiode et al. 2013 (MNRAS 430, 1736) showed that these modes are more easily detectable in massive than in solar-type stars. However, Be stars are very rapid rotators and stochastic excitation is enhanced by rapid rotation, through the Coriolis acceleration which modifies gravity waves. This has been demonstrated analytically (Mathis et al. 2014, A&A 565A, 47) and observed in numerical simulations (Rogers et al. 2013, ApJ 772, 21). Indeed, in the convective zones, when rotation is rapid, gravity modes become less evanescent in the super-inertial regime and propagative inertial modes in the sub-inertial regime. Such stochastic modes are thus probably present in all rapidly rotating massive stars.
Lee (2013, PASJ 65, 122) showed that gi modes excited by the κ mechanism transport angular momentum and could play a role in the Be phenomenon. However, in the sub-inertial regime, the transport of angular momentum was believed to become less efficient because of gi waves equatorial trapping (Mathis et al. 2008, SoPh 251, 101; Mathis 2009, A&A 506, 811). Our recent work shows that transport by trapped sub-inertial waves may be sustained in rapidly rotating stars thanks to the stronger stochastic excitation by turbulent convective flows. Moreover, sub-inertial gi modes have very low frequencies and therefore they transport more angular momentum than modes with higher frequencies.
We thus proposed that this mechanism allows to transport angular momentum from the convective core of Be stars to their surface. The accumulation of angular momentum just below the surface of Be stars increases the surface velocity, which then reaches the critical velocity needed to eject material from the star (Neiner et al. 2013, ASPC 479, 319; Lee et al. 2015, MNRAS 443, 1515).
Unfortunately, the nominal Kepler mission did not observe classical Be stars and only a few of

these stars were observable (and observed) so far in K2 fields. K2's Field 9, however, contains many classical Be stars. We propose to test the scenario devised from CoRoT observations by observing these classical Be stars in Field 9.

Immediate objectives

Our first goal is to investigate whether the observed classical Be stars show stochastic gi modes in addition to the kappa-driven g and p pulsation modes, to confirm that these gi modes are common in Be stars and are a signature of the Be phenomenon. Second, we will apply the seismic modelling tool we recently develop to model the kappa-driven and stochastic gi modes. We will then be able to compute the transport of angular momentum from the core of the Be stars to their surface. If this angular momentum transport is sufficient, it would confirm our proposed scenario that gi modes are those that enhance the transport of momentum, leading the surface layer to reach critical velocity and thus igniting the ejection of material from the surface to the Keplerian circumstellar disk. In addition, for 2 Be stars observed with CoRoT it has been possible to derive the extent of the convective core (Neiner et al. 2012, A&A 539A, 90). This is very important to quantify the effect of rapid rotation on the internal structure of stars. We expect that this will be possible for most classical Be stars observed with K2 as well and we will thus attempt to derive the size of convective cores of all oberved Be stars. Finally, most of our targets in Field 9 are early-type Be stars, i.e. prone to have frequent outbursts, contrary to late Be stars for which outbursts are rarer. Some of them may thus undergo an outburst during the K2 observations. This has been observed in only one star with CoRoT and would be a perfect test for our scenario.

Classical Be targets

Field 9 contains 26 confirmed classical Be stars with $8 \leq V \leq 11$ that fall on silicon. We request K2 observations of all of them. Pulsations of Be stars are of the order of 1 day, therefore long cadence observations are sufficient for these targets. We have already developed tools to construct lightcurves from the provided pixel data and to correct for any remaining effects of the roll of the satellite (Buysschaert et al. 2015, MNRAS 453, 89).

Long-term legacy value of the program

Space-based photometric observations over more than 5 weeks are available for only a few classical Be stars, all observed with CoRoT. The data acquired with K2 for classical Be stars will thus for the first time allow us to have a statistically significant sample of Be stars. Moreover, since classical Be stars include many physical ingredients (rapid rotation, several types of pulsations, circumstellar material,...), they are also a very rich source of information and each classical Be star observed with CoRoT led to new discoveries. In the same way, the K2 data of classical Be stars will provide a wealth of information on those stars, which can also be compared to other types of B stars. There is thus a large discovery and legacy space in these K2 observations.

Observations in previous K2 Fields

All classical Be stars available in all previous K2 Fields have been requested, and 14 of them (mostly late-type Be stars) have been observed. Their data are currently being analysed. In the same way, future K2 fields do not include many classical Be stars. On the contrary, Field 9 is a particularly interesting field for hot stars in general, and for classical Be stars in particular, since it contains 26 of them and they are almost all early-type ones. Field 9 is thus our chance to increase the K2 science on these objects drastically.