Pulsations and outbursts in Be stars: Small differences – big impacts

D. Baade[1], Th. Rivinius[2], A. Pigulski[3], A. Carciofi[4], G. Handler[5], R. Kuschnig[6,7], Ch. Martayan[2], A. Mehner[2], A. F. J. Moffat[8], H. Pablo[8], A. Popowicz[9], S. M. Rucinski[10], G. A. Wade[11], W. W. Weiss[6] and K. Zwintz[12]

1. European Organisation for Astronomical Research in the Southern Hemisphere, Karl-Schwarzschild-Str. 2, 85748 Garching b. München, Germany
2. European Organisation for Astronomical Research in the Southern Hemisphere, Casilla 19001, Santiago 19, Chile
3. Astronomical Institute, Wrocław University, Kopernika 11, 51-622 Wrocław, Poland
4. Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, Rua do Matão 1226, Cidade Universitária, 05508-900 São Paulo, SP, Brazil
5. Nicolaus Copernicus Astronomical Center, ul. Bartycka 18, 00-716 Warsaw, Poland
6. University of Vienna, Institute for Astrophysics, Tuerkenschanzstrasse 17, 1180 Vienna, Austria
7. Graz University of Technology, Institute of Communication Networks and Satellite Communications, Inffeldgasse 12, 8010 Graz, Austria
8. Département de physique and Centre de Recherche en Astrophysique du Québec (CRAQ), Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, Québec, H3C 3J7, Canada
9. Institute of Automatic Control, Silesian University of Technology, Gliwice, Poland
10. Department of Astronomy & Astrophysics, University of Toronto, 50 St. George St, Toronto, Ontario, M5S 3H4, Canada
11. Department of Physics, Royal Military College of Canada, PO Box 17000, Stn Forces, Kingston, Ontario K7K 7B4, Canada
12. Universität Innsbruck, Institute for Astro- and Particle Physics, Technikerstrasse 25/8, A-6020 Innsbruck, Austria

Abstract: New high-cadence observations with BRITE covering many months confirm that coupled pairs of nonradial pulsation modes are widespread among early-type Be stars. With the difference frequency between the parental variations they may form a roughly sinusoidal variability or the amplitude may cyclicly vary. A first — amplified — beat pattern is also found. In all three cases the amplitudes of difference frequencies can exceed the amplitude sum of the base frequencies, and modulations of the star-to-circumstellar-disk mass-transfer rate may be associated with these slow variations. This suggests more strongly than any earlier observations that significant dissipation of pulsational energy in the atmosphere may be a cause of mass ejections from Be stars. A unifying interpretative concept is presented.

1 Introduction

In a multi-parameter space, Be stars occupy a volume that is disjoint with all other types of hot stars, regardless of their evolutionary stage:

- Be stars show the largest equatorial velocities of all non-degenerate stars.

- Be stars possess self-ejected Keplerian disks, which may develop as well as completely disperse on timescales of months to years.
- In UV resonance lines, Be stars exhibit classical wind profiles. These are probably mainly due to radiative ablation of the disk.
- Companion stars with periods less than a month are rare.
- At least on large scales, Be stars are the least magnetic group of hot stars.

For a broader initiation to the Be phenomenon see Rivinius et al. (2013).

In many B stars, rapid rotation and nonradial pulsation seem to be necessary conditions for this so-called Be phenomenon to occur, as the rest of this paper will demonstrate. The rapid rotation may be native (Martayan et al., 2007) or acquired along the evolutionary path of a binary (McSwain & Gies, 2005):

- In a few Be stars, a hot sub-dwarf O-type (sdO) companion has been detected by its He-ionizing effect on the disk (e.g., Peters et al., 2016). The progenitor of the sdO has dumped mass and angular momentum on the present Be primary.
- Some Be stars have high space velocities (Berger & Gies, 2001) that could be the result of the disruption of a binary by either a close encounter in a dense environment or the supernova explosion of a former massive companion.
- In Be X-ray binaries, a supernova product is still present in the form of a neutron star (evidence for black holes is weak) (Walter et al., 2015).

Even the sum of these three processes would probably not account for Be-star frequencies reaching $> 30\%$ at spectral type B1 (Zorec & Briot, 1997). Most Be-star disks, if any, are not accretion disks evidencing ongoing mass transfer in a binary (but see also Harmanec et al., 2002). Viscous processes and radiative ablation destroy Be disks in a few years (Haubois et al., 2014; Kee et al., 2016) so that they do not trace earlier evolutionary stages. In classical Be stars, the disk matter is decreted by the central B star. Viscosity enables tossed-up matter to exchange angular momentum so that $\sim$1% can attain Keplerian velocities while the bulk of the ejecta falls back to the star (Haubois et al., 2014).

Earlier spectroscopy (e.g., Baade et al., 1988) found rapid outbursts in Be stars. They even repeat cyclically (Rivinius et al., 1998), when two NRP modes are temporarily in phase and co-add their amplitudes. BRITE (Weiss et al., 2014) has enabled the most detailed description to date of these processes (Baade et al., 2016, 2017a), which is expanded below. More holistic analyses using wavelet transforms of CoRoT and Kepler space photometry were performed by Rivinius et al. (2016, and in prep.). But it still remains unclear whether all outbursts of a given Be star are due to the same mechanism and whether pulsations play a decisive role in all Be stars.

2 BRITE observations of selected Be stars

Pre-BRITE observations indicating a link between NRP and mass loss were often attributed to multi-mode beat processes. Rivinius et al. (1998) inferred this from the modulation of the strength of the Hα emission of μ Cen with frequency differences among a few NRP modes. In photometry, outbursts are typically diagnosed from changes in the mean brightness. They probably result from varying amounts of circumstellar matter, which reprocesses the stellar flux it receives and partly redirects it to, or away from, the observer, depending on viewing angle (Haubois et al., 2014). In the additive case, it is kind of an active light echo. Space photometry contributed the important fact that power spectra can look substantially different during outbursts than during quiescence. Some individual NRP amplitudes decrease, many increase, and especially quasi-dense groups of not strictly constant frequencies develop or grow (Huat et al., 2009; Rivinius et al., 2016). Accordingly, the picture was generalized to the notion that a large number of NRP modes may, in a collective beat process, energize outbursts (e.g., Huat et al., 2009; Kurtz et al., 2015).

Unexpectedly, BRITE-Constellation has not yet found beat phenomena but only genuine NRP mode couplings which present themselves as a roughly sinusoidal large-amplitude variability with a frequency close to the difference (called Δ frequency below) between the two parent frequencies (Baade et al., 2016, 2017a). There are indications that mass-loss rates can be modulated with Δ frequencies.

The next two subsections illustrate both types of mode combinations; the third one describes observations that do not fall into either of these categories. They extend the previous overview by Baade et al. (2017a). 'Blue' and 'red' denote observations with blue- or red-sensitive BRITE satellites (Weiss et al., 2014).

2.1 Large-amplitude Δ frequencies

The initial prototypes of this variability were η Cen (Baade et al., 2016) and 28 Cyg (Baade et al., 2017b). New examples include:

- **10 CMa** (B2, $m_V = 5.2$): In 2015, the (blue) amplitude, 13.7 mmag, of the Δ frequency at $0.0140\,d^{-1}$ was slightly larger than the amplitude sum of its parent frequencies: $1.3363\,d^{-1}$ (7.7 mmag) and $1.3501\,d^{-1}$ (5.1 mmag). There were also strong frequency groups at $0.55-0.75\,d^{-1}$ and around $1\,d^{-1}$.
- **27 CMa** (B3, $m_V = 4.7$): In 2015, a (red) Δ frequency, $0.0560\,d^{-1}$ (2.0 mmag), appeared as the difference between $2.6825\,d^{-1}$ (2.3 mmag) and $2.6257\,d^{-1}$ (2.4 mmag). There were further frequencies at $1.2678\,d^{-1}$ and $1.3573\,d^{-1}$ with comparable (semi-) amplitudes, namely 2.1 mmag and 1.8 mmag. The largest amplitude, 4.4 mmag, was associated with a fairly isolated peak at $0.7920\,d^{-1}$.
- **25 ψ^1 Ori** (B1, $m_V = 5.0$): This star abounds in frequency groups so that plenty of Δ frequencies can be construed (cf. Baade et al., 2017a). The two relatively most isolated peaks in the 2015 blue power spectrum appeared at $1.4889\,d^{-1}$ and $1.6784\,d^{-1}$ with large amplitudes: 12.7 mmag and 10.4 mmag. In other Be stars, amplitudes above $\sim$10 mmag often identify the strongest in a group and/or are Štefl frequencies (Baade et al., 2016; Rivinius et al., 2016), both of which have at least partially strong and variable circumstellar roots. Clear frequency groups existed around 0.2, 1.3, and $2.8\,d^{-1}$.

  The strongest power peak in the first group was at $0.1886\,d^{-1}$ (20.3 mmag), which is close to $0.1895 = 1.6784 - 1.4889\,d^{-1}$ and, therefore, a Δ frequency. Figure 3 reveals in full detail what dramatic effects can be associated with Δ frequencies. The overall structure of the light curve is governed by two series of outbursts, one each at the beginning and end of its time coverage. On shorter timescales, the outbursts imprint a conspicuous structure with the Δ frequency, $0.19\,d^{-1}$. But there is no beat pattern of the parent frequencies, $1.49\,d^{-1}$ and $1.68\,d^{-1}$. Neither does the Δ frequency appear as a steady sinusoidal modulation as in η Cen (Baade et al., 2016) and 28 Cyg (Baade et al., 2017b). Instead, the *amplitude* of the Δ frequency is strongly modulated. Unfortunately, the time span of the observations is not long enough to reveal whether the series of outbursts repeat every three months.

  The light curve contains an additional special detail. During the outburst series, there are not just brightenings, which probably are circumstellar light echoes,

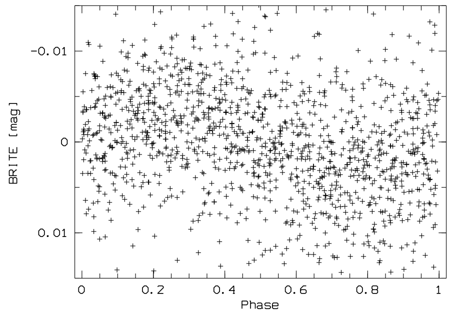

Fig. 1: BRITE photometry of γ Cas folded with $f = 2.479\,\mathrm{d}^{-1}$.

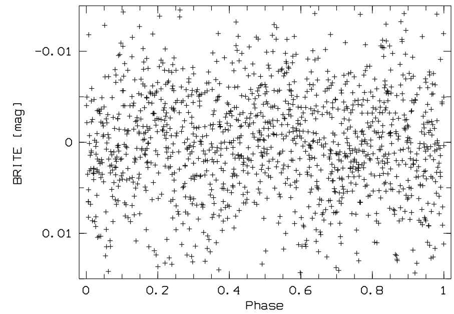

Fig. 2: Ditto except for $f = 0.8225\,\mathrm{d}^{-1}$.

but also fadings. They occur in both blue and red data confirming they are real variations. The nature of the effects of ejected matter, brightening or dimming, depends on aspect angle (Haubois et al., 2014). In a given star, this angle is constant, and so the observations contain constraints on the width in stellar latitude of the mass-exchange process between star and disk.

In γ Cassiopeiae (B0.5, $m_V = 2.4$) two parent variations ($2.1950\,\mathrm{d}^{-1}$, 0.9 mmag, and $2.4796\,\mathrm{d}^{-1}$, 2.7 mmag), of which the weaker one may be a member of a frequency group, gave rise in 2015 to a Δ frequency at $0.27\,\mathrm{d}^{-1}$ and low amplitude (1.1 mmag). A second major variability (2.2 mmag) was at $0.9728\,\mathrm{d}^{-1}$.

Among these inconspicuous frequencies, $2.4796\,\mathrm{d}^{-1}$ is the most interesting (Fig. 1). It is close to three times $0.8225\,\mathrm{d}^{-1}$ (amplitude from 0 to 3 mmag) which Henry & Smith (2012) found in 15 seasons (1997-2011) of single-site ground-based photometry. Our analysis of seven years (2002 – 2011) of observations with SMEI (Jackson et al., 2004) confirms its reality. Smith et al. (2016) use this frequency as an anchor quantity of their magnetically-controlled rotational-modulation model which interprets it as the rotation period of the primary in the 200-d binary. This 0.8225-d^{-1} frequency is not seen in the BRITE observations (Fig. 2). A three times faster rotation would stretch the model of Smith et al. (2016) beyond its limits because its authors state that even their lower frequency would imply 1.15 ± 0.15 fractional critical rotation. They propose γ Cas as the prototype of hard X-ray emitting Be stars. The BRITE power spectrum appears rather normal but the apparent frequency tripling is quite unusual.

2.2 Beat phenomena

The spectroscopic frequencies and difference frequencies (Rivinius et al., 1998) of μ Cen (B2, $m_V = 3.4$) were not detected with BRITE (Baade et al., 2016). The large-amplitude (~250 mmag peak to peak in the red BRITE passband) variability is due to a light echo, which varies with the amount of matter present in the inner disk. Conceivably, these light echoes are not good clocks so that the stellar frequencies are not (well) reproduced. κ CMa ($m_V = 3.7$) not only has a similar spectral type (B1.5 vs. B2) but also a comparable $v \sin i$ (220 vs. $155\,\mathrm{km\,s}^{-1}$) and is probably viewed at a similar, perhaps slightly higher, inclination angle. Rivinius et al. (2003) found two spectroscopic frequencies, $0.548\,\mathrm{d}^{-1}$ and $0.617\,\mathrm{d}^{-1}$ and also discuss discrepant pho-

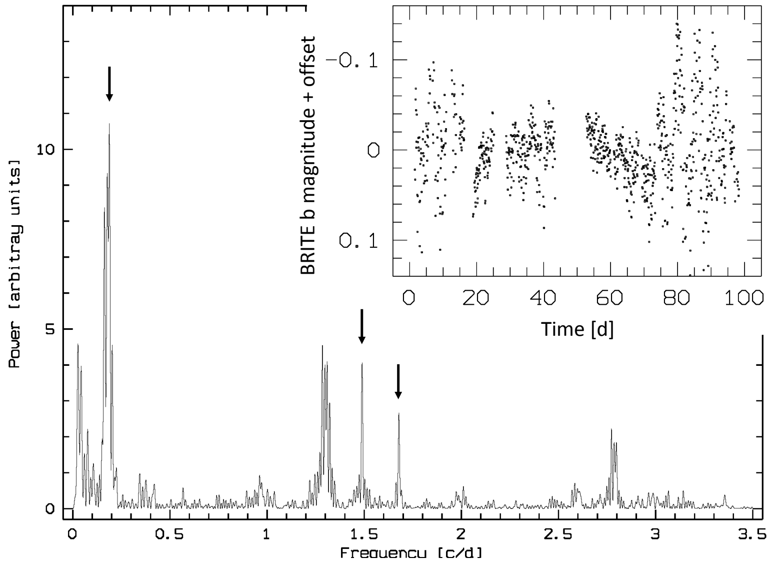

Fig. 3: Power spectrum of the BRITE blue-channel observations of 25 ψ^1 Ori in 2014. Arrows mark the Δ frequency and its parent frequencies. The insert shows the lightcurve.

tometric frequencies; the line-profile variability associated with the lower frequency is different from the typical $\ell = +m = 2$ variety. They are not visible in the BRITE red photometry from 2015, which is dominated by outbursts that repeat cyclicly with about $0.0557\,\mathrm{d}^{-1}$. All three frequencies deserve further observational attention because the large range of $\sim$150 mmag suggests that the low frequency is due to a light echo. The proximity to a Δ-frequency relation may be just spurious, or one or more of the frequency values are incorrect. However, if the deviation from a Δ-frequency relation contains a component from the orbital phase velocity of an inhomogeneous or non-circular circumstellar mass distribution, it could carry important diagnostics of the star-disk interaction region.

In all the many BRITE Be-star light curves, genuine beat patterns are a rare sight although all stars are multi-frequency variables. They may be veiled by light echoes and atmospheric amplitude amplification processes. Moreover, members of dense frequency groups, which are probably largely circumstellar (Baade et al., 2016; Rivinius et al., 2016), are often not strictly phase coherent and therefore cannot form beat patterns. But the paucity of beat patterns is still remarkable.

28 ω CMa (B2, $\mathrm{m_V} = 3.8$) is one of the first Be stars in which nonradial pulsation was suspected (Baade, 1982). The initial frequency of $0.73\,\mathrm{d}^{-1}$ was approximately confirmed by various other spectroscopic studies (e.g., Štefl et al., 1999). In the blue BRITE power spectrum (data from 2015) only a low-significance peak at $0.7273\,\mathrm{d}^{-1}$ is found. This appears not surprising because in pole-on stars like 28 ω CMa ($v \sin i = 80\,\mathrm{km\,s}^{-1}$), the latitudinal component of the velocity field of quadrupole NRP modes is maximally visible (Rivinius et al., 2003) whereas the photometric signature may well be azimuthally averaged out to near-invisibility. However, after subtraction of the enormous $\sim$150/200-mmag (blue/red) peak-to-peak variability, which is a light echo as in μ Cen (Baade et al., 2016), κ CMa (Sect. 2.1), and many

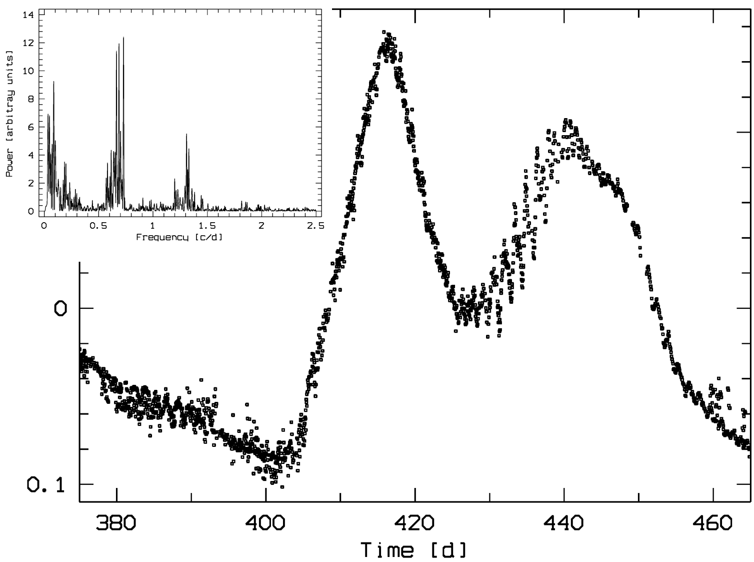

Fig. 4: Red light curve of 28 CMa obtained with BRITE in 2015. Note the various phases with enhanced activity, very similar to beat patterns and most prominent from 430 d to 440 d where the spacing of the wiggles is consistent with frequencies in the group near $0.7\,\mathrm{d}^{-1}$. The insert displays the power spectrum of the data corrected for the very high-amplitude, slow light-echo variability.

others, it becomes evident that $0.73\,\mathrm{d}^{-1}$ is amidst a frequency group extending from 0.55 to $0.8\,\mathrm{d}^{-1}$. This explains the insuccessful efforts to improve the spectroscopic frequency. The group also includes this star's Štefl frequency at $0.68\,\mathrm{d}^{-1}$ (Štefl et al., 1999). The mean (semi-)amplitudes of the highest peaks reach ∼2.5 mmag. A second frequency group exists between 1.15 and $1.45\,\mathrm{d}^{-1}$.

In Fig. 4, the power spectrum after removal of the slow large-scale variability and part of the un-cleaned light curve are presented. The most important detail lies in the series of wiggles identified in the caption to the figure. The wiggle spacing is consistent with frequency values in the $0.55-0.8\,\mathrm{d}^{-1}$ group. Their peak-to-peak range, ∼50 mmag, is in the light-echo domain and an order of magnitude larger than the amplitudes in the frequency group. This large amplification supersedes the expected classical beat pattern. Since these tremolos are visible most of the time, it is not currently possible to conclude whether they can be the cause of the slow large-amplitude variability, i.e. major ejections of matter. Special interest exists in finding out whether the series of outbursts repeat every ∼75 days as seems possible from the present data. $1/75\,\mathrm{d} = 0.013\,\mathrm{d}^{-1}$ could, then, be called a Δ frequency.

2.3 Orphan frequencies and other variabilities

Not all low-frequency variabilities can be traced back to a difference between two higher (NRP) frequencies. Some of these 'orphan frequencies' are of the order of $2/T$, where T is the total time span of the observations, but closely spaced frequency peaks should still be resolvable. The existence of Δ frequencies with similar properties suggests that there is a good chance of many of the orphan frequencies also being real.

Independent support may be derived from the report by Labadie-Bartz et al. (2017) of even lower frequencies (down to $\sim$0.005 d^{-1}) in ground-based long-term photometry of 610 Be stars. BRITE examples include:

- ω **Ori** (B3, $m_V = 4.6$) exhibited slow (red) variability with 0.0275 d^{-1} in 2014 (9.4 mmag) and 0.0416 d^{-1} in 2025 (7.6 mmag). In 2014, the main (red) rapid variability was at 1.0519 d^{-1} (9.9 mmag) but in 2015 there were instead two similarly strong variations at 0.9872 d^{-1} (6.9 mmag) and 1.0719 d^{-1} (6.5 mmag). All three higher frequencies are embedded in a frequency group that is broad enough to easily construct from its ranks the low frequencies as Δ frequencies.
- **FW CMa** (B2, $m_V = 5.2$): The red light curve (from 2015) of this extreme pole-on star (40 km s^{-1}, Rivinius et al., 2003) is not too badly approximated by a single frequency, 0.0506 d^{-1}. Maxima and minima are fairly peaked (as opposed to sinusoidal), and small changes in shape and considerable amplitude variations give rise to the suspicion that the true nature of the variability is a beat process. But the power spectrum does not reveal any candidate parent frequencies; the spectroscopic frequency of 1.192 d^{-1} (Rivinius et al., 2003) is not detected. The amplitudes grew over four months from $\sim$10 mmag to $\sim$30 mmag. Overall, this light curve of FW CMa can be described as being very similar to that of 25 ψ^1 Ori except for a stretch in time by a factor of a few.

A special, so far singular, case is 60 Cyg (B1, $m_V = 5.4$). In 2015, it featured two (red) frequency pairs: (i) 1.8672 d^{-1} (2.4 mmag) and 1.8867 d^{-1} (3.3 mmag) as well as (ii) 3.7538 d^{-1} (2.6 mmag) and 3.7726 d^{-1} (2.4 mmag). In both pairs the frequencies differed by 0.19 d^{-1}. Moreover, the higher frequencies in the two pairs are harmonics. But there was no obvious variability with 0.19 d^{-1}. At 3.3336 d^{-1} 60 Cyg had the strongest (6.4 mmag) variability above 2.5 d^{-1} so far seen with BRITE.

3 Summary, conclusions, and outlook

Observations with BRITE-Constellation have established that in Be stars pairs of NRP modes can couple to form a sinusoidal variability with their difference (Δ) frequency or a beat pattern. Both may reach amplitudes above the amplitude sum of the parent modes, which signals (as light echoes), maybe enables, mass-loss outbursts. The coupling seems highly selective, and most combinations of NRP modes have no visible effect (this conclusion assumes broadly correct distinction between stellar NRP modes and circumstellar frequencies, see below). The sensitivity of BRITE is not sufficient to investigate the behaviour of frequency groups because the frequencies are time dependent. They may harbour a similar mechanism involving the collective power of many elementary variabilities. While the evidence for outbursts due to coupled NRP modes seems overwhelming, such evidence is not found in similarly many other Be stars observed by BRITE. Explanations include:

- The stars are inactive for extended periods of time.
- The aspect-angle-dependent amplitudes of NRP modes are too low.
- The stellar variability is masked by circumstellar light echoes.

All stars discussed in this paper are of spectral type B3 or earlier. This introduces a strong bias towards higher activity (Labadie-Bartz et al., 2017; Baade et al., 2017a).

A larger sample would permit searches for trends with aspect angle ($v \sin i$) and for differences between stellar and circumstellar variabilities. An estimator of the latter may be the environment in the power spectrum. If it consists of a rich group, the phase coherence is often lower (Baade et al., 2016; Rivinius et al., 2016), which might be more readily reconciled with circumstellar conditions. Amplitudes above ∼10 mmag may also more commonly have a circumstellar component (see below). If quadrupole modes are also photometrically dominant, the nearly perfect pole-on star FW CMa demonstrates that the large-amplitude variability is circumstellar. There is no obvious wavelength dependency of the amplitudes but colour variations may be different for stellar (bluer?) and circumstellar (redder?) variations.

Multi-season observations would gain in scope towards repetition frequencies of major outbursts, which may be as low $0.0003\,\mathrm{d}^{-1}$ or less (e.g., Ghoreyshi et al., 2015), and also enable searches for the origins of orphan frequencies. Other goals include the comparison of the angular 4π structure of Δ variations to that of their parent NRP modes and the localization of the amplitude amplification process.

The central task is the development, if possible, of a unifying scheme. It could look as follows: Via some unknown selection mechanism, two NRP modes couple to form a Δ frequency. Because of the increased combined amplitude (and with much rotational support), they cause cyclicly repeating mass-loss outbursts. Large amplitudes of Δ frequencies arise as circumstellar light echoes. They trace the combined and integrated effects in the inner disk of mass injection and viscous and radiative gas dispersal. This can be different from the amount of mass instantaneously ejected.

In η Cen and 28 Cyg, the amount of inner-disk matter varies sinusoidally with a Δ frequency of constant amplitude. In 25 ψ^1 Ori and FW CMa, this light modulation exhibits a time-dependent amplitude and is akin to a beat pattern. Only 28 CMa exhibits bona-fide beat patterns of frequencies in the NRP range (which is slightly surprising as the frequencies in the groups are not really phase coherent). Within the light-echo paradigm this suggests that effects of individual pulsation cycles are seen. In the absence of other evidence, one can only speculate whether in the other stars there may be a high-frequency cut-off somewhere.

Particularly interesting is the amplitude amplification of the higher frequencies. This could also be the base mechanism of the Δ frequency amplitude variability in 25 ψ^1 Ori and FW CMa: the beat amplitude is not enhanced as such but merely as a consequence of growing amplitudes of the base variabilities. The reason for the variation in amplitude of the higher frequencies may be in the disk or the star or both. Finally, if several Δ frequencies coexist, as perhaps in μ Cen and 28 CMa, the superimposed light echoes can be impossible to unravel from 'just' half a year worth of data, especially if not fully periodic.

The extension in timescale to a decade may require correspondingly low Δ frequencies, which would hardly be directly detectable. However, if there were two (or more) outburst patterns which can be distinguished as patterns, extremely low superΔ frequencies could be indirectly derived. The duration of the associated outbursts would, then, depend on the length of the phase interval, during which high mass loss can be sustained by the involved pairs of NRP modes.

The two-coupled-NRP-modes paradigm is a useful approximative description of the observations. If the frequencies are not constant and embedded in a dense group, the overall process may be highly stochastic if not chaotic. This could include rogue-wave-like events. Where present, the semi-regular repetition of outbursts would argue against excessive randomness. But in many Be stars observed at sufficient spectral resolution and S/N, higher-order line-profile variability has been detected (Vogt & Penrod, 1983), which provides an additional activity floor.

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References

Baade, D., *An unusually short stable period of absorption line asymmetries and V/R variations in the spectrum of the Be star 28 CMa*, A&A **105**, 65 (1982)

Baade, D., et al., *Time-resolved high-resolution spectroscopy of an Hα outburst of μ Centauri (B2IV-Ve)*, A&A **198**, 211 (1988)

Baade, D., et al., *Short-term variability and mass loss in Be stars. I. BRITE satellite photometry of η and μ Centauri*, A&A **588**, A56 (2016)

Baade, D., et al., *Difference frequencies of nonradial pulsation modes and repetitive outbursts in classical Be stars*, in A. Miroshnichenko, S. Zharikov, D. Korčáková, M. Wolf (eds.) The B[e] Phenomenon: Forty Years of Studies, *Astronomical Society of the Pacific Conference Series*, volume 508, 93 (2017a)

Baade, D., et al., *Short-term variability and mass loss in Be stars III. BRITE and SMEI satellite photometry of 28 Cygni*, *ArXiv e-prints* (2017b), `1708.07360`

Berger, D. H., Gies, D. R., *A Search for High-Velocity Be Stars*, ApJ **555**, 364 (2001)

Ghoreyshi, M. R., et al., *Modeling the Complete Lightcurve of ω CMa*, ASP Conf. Series **506**, 315 (2015), `arXiv:1506.08902`

Harmanec, P., et al., *On the role of duplicity in the Be phenomenon. I. General considerations and the first attempt at a 3-D gas-dynamical modelling of gas outflow from hot and rapidly rotating OB stars in binaries*, A&A **396**, 937 (2002)

Haubois, X., et al., *Dynamical Evolution of Viscous Disks around Be Stars. II. Polarimetry*, ApJ **785**, 12 (2014)

Henry, G. W., Smith, M. A., *Rotational and Cyclical Variability in γ Cassiopeiae. II. Fifteen Seasons*, ApJ **760**, 10 (2012)

Huat, A.-L., et al., *The B0.5IVe CoRoT target HD 49330. I. Photometric analysis from CoRoT data*, A&A **506**, 95 (2009)

Jackson, B. V., et al., *The Solar Mass-Ejection Imager (SMEI) Mission*, Sol. Phys. **225**, 177 (2004)

Kee, N. D., Owocki, S., Sundqvist, J. O., *Line-driven ablation of circumstellar discs - I. Optically thin decretion discs of classical Oe/Be stars*, MNRAS **458**, 2323 (2016)

Kurtz, D. W., et al., *A unifying explanation of complex frequency spectra of γ Dor, SPB and Be stars: combination frequencies and highly non-sinusoidal light curves*, MNRAS **450**, 3015 (2015)

Labadie-Bartz, J., et al., *Photometric Variability of the Be Star Population*, AJ **153**, 252 (2017)

Martayan, C., et al., *Effects of metallicity, star-formation conditions, and evolution in B and Be stars. II. Small Magellanic Cloud field of NGC 330*, A&A **462**, 683 (2007)

McSwain, M. V., Gies, D. R., *The Evolutionary Status of Be Stars: Results from a Photometric Study of Southern Open Clusters*, ApJS **161**, 118 (2005)

Peters, G. J., Wang, L., Gies, D. R., Grundstrom, E. D., *The Hot Companion and Circumbinary Disk of the Be Star HR 2142*, ApJ **828**, 47 (2016)

Rivinius, T., Baade, D., Carciofi, A., *Short-term variability and mass loss in Be stars. II. Physical taxonomy of photometric variability observed by the Kepler spacecraft*, A&A **593**, A106 (2016)

Rivinius, T., Baade, D., Štefl, S., *Non-radially pulsating Be stars*, A&A **411**, 229 (2003)

Rivinius, T., Carciofi, A. C., Martayan, C., *Classical Be stars. Rapidly rotating B stars with viscous Keplerian decretion disks*, A&A Rev. **21**, 69 (2013)

Rivinius, T., et al., *Stellar and circumstellar activity of the Be star μ Centauri. I. Line emission outbursts*, A&A **333**, 125 (1998)

Smith, M. A., Lopes de Oliveira, R., Motch, C., *The X-ray emission of the γ Cassiopeiae stars*, Adv. Space Research **58**, 782 (2016)

Štefl, S., Aerts, C., Balona, L. A., *Simultaneous photometry and spectroscopy of the Be star 28 (ω) CMa - I. Observational evidence of the periodic components of rapid variability*, MNRAS **305**, 505 (1999)

Vogt, S. S., Penrod, G. D., *Detection of high-order nonradial oscillations on the rapid rotator ζ Ophiuchi and their link with Be type outbursts*, ApJ **275**, 661 (1983)

Walter, R., Lutovinov, A. A., Bozzo, E., Tsygankov, S. S., *High-mass X-ray binaries in the Milky Way. A closer look with INTEGRAL*, A&A Rev. **23**, 2 (2015)

Weiss, W. W., et al., *BRITE-Constellation: Nanosatellites for Precision Photometry of Bright Stars*, PASP **126**, 573 (2014)

Zorec, J., Briot, D., *Critical study of the frequency of Be stars taking into account their outstanding characteristics*, A&A **318**, 443 (1997)