The Be Phenomenon in Early-Type Stars, IAU Colloquium 175
ASP Conference Series, Vol. 214, 2000
M. A. Smith, H. F. Henrichs, and J. Fabregat, eds.

Tracing the Transient Periods in the Be Star 28 ω CMa

S. Štefl, A. Budovičová

Astronomical Institute, Academy of Sciences of the Czech Republic

D. Baade, A. Kaufer

European Southern Observatory, Garching, Germany

T. Rivinius, O. Stahl, B. Wolf

Landessternwarte Königstuhl, Heidelberg, Germany

Abstract. Spectra of the Be star 28 CMa obtained with the HEROS echelle spectrograph in 1996 and 1997 were used to check the presence of transient periods in commonly measured scalar parameters of absorption and emission lines. Transient periods can be convincingly detected in modes of higher absorption and single peak emission lines of the Balmer series as well as in the V/R ratio of Fe II lines. Consequences for the frequency analyses of datasets containing radial velocities derived from different ions are discussed. The significant differences in amplitudes of radial velocities of different ions and in individual seasons were confirmed and a mean ephemeris derived.

1. Introduction

28 (ω) CMa (HR 2749 = HD 56 139; B2 IV-Ve, $v \sin i =$ 80 km/s) is characterized by strong Hα emission of E/C = 3.6 – 4.6 in 1996, but as much as 7.2 – 7.6 in 1997, as well as by radial velocity (RV) and line profile variations (lpv) with a period of 1.37 d (Baade 1982a,b). A transient period of 1.49 d was detected in the 1996 lpv (Štefl et al., 1998). Harmanec (1998) concluded that the RV variations cannot be described with a constant period of 1.37 d and suggested that the period undergoes slow and probably cyclic changes on a time scale of tens of years. Both 1.37 and 1.49 d periods can be detected in residual light variations after prewhitening for medium term variations of larger amplitudes. The amplitude ratio of the two periods varies on a time scale of years (Štefl et al., 1999). Balona et al. (1999) modeled the He I 6678 lpv and proposed that it can be described best by a near-photosphere patch with large turbulent broadening. On the other hand, Maintz et al. (this volume) found that the lpv in various transitions of a larger number of ions can be well modeled as non-radial pulsation using the BRUCE code by Townsend (1998).

The term "transient periodicities" was introduced by Štefl et al. (1998) for the temporary secondary periodicities in their analysis of HEROS spectra of

https://doi.org/10.1017/S0252921100055913 Published online by Cambridge University Press

28 CMa, μ Cen and η Cen. Their main properties can be summarized as follows:

- they appear at times of emission outbursts and co-exist with the persistent primary periodic variations of the stellar line profiles for several days (μ Cen) up to a month (28 CMa).
- they have a double-peaked power distribution across the line profiles with maxima further in the wings compared to the primary periods. Maximum power appears close to or even beyond $v \sin i$.
- they attain significant strength only in lines formed (also) above the photosphere, but neither in purely photospheric lines nor in those originating from the most distant parts of the circumstellar disk.
- they do not re-appear with the same period as in the previous epoch. In μ Cen, the transient periods excited during different outbursts fall in an interval of about $\pm 10\%$.
- so far, not more than one transient period was detected at any given time.

The only qualitative interpretation up to now was proposed by Rivinius et al. (1998) for μ Cen. The transient periodicities are thought to reflect the orbital motion of clouds ejected during emission outbursts.

The aim of this study is to check the presence of transient periodicities in commonly measured spectral quantities of absorption and emission lines and to investigate their impact on time series analyses of these parameters.

2. Observations and methods of analysis

More than 200 spectra obtained with the HEROS spectrograph (for more details see Štefl & Rivinius, this volume) have been used. The ESO La Silla 0.5m telescope has been used in January–May 1996 (99 spectra each in the blue and red channel) and January–April 1997 (119 spectra in the blue and 104 in the red channel).

The *RV*'s of absorption and emission lines were derived as modes (the wavelength positions of the minimum/maximum flux in the line profile) by fitting Gaussians interactively. By a similar fit for emission lines the strengths of the *V* and *R* emission components were found. The time series analysis was done with the help of ESO MIDAS, extended by a special time series analysis package developed by A. Kaufer. The Fortran code FOTEL, developed by P. Hadrava, was used for *RV* solutions.

3. Time series analysis of absorption and emission lines

A time series analysis was performed on the modes of sixteen He I lines and three H I absorption lines little influenced by emission, namely H I 3734, 3750, 3770.

Fig. 1 (left) shows the typical AOV (analysis of variance) periodograms of the modes of absorption lines. The variations of He I 7065, typical for He I lines, are monoperiodic in both seasons. Strong power appears at the photospheric frequency of 0.73 c/d, but there is no significant peak at the transient frequency 0.68 c/d. Modes of H I lines show a rather different character of periodicity. The

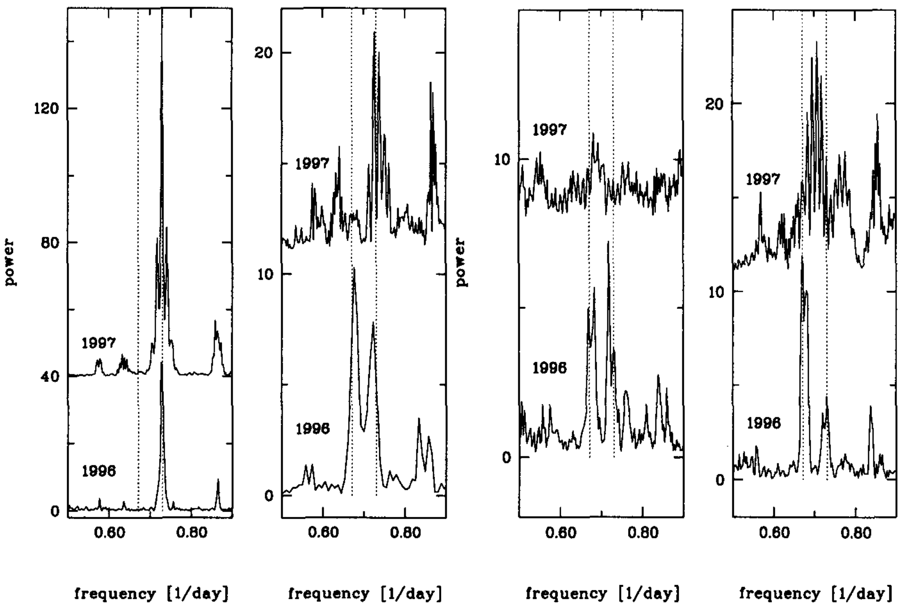

Figure 1. Left: The AOV periodograms for absorption lines in 1996 and 1997: He I 7065 (left) and the mean modes of H I 3734, 3750 and 3770 (right). Dotted vertical lines mark the transient (0.68 c/d, left) and photospheric (0.73 c/d) frequencies. Right: AOV periodograms for emission lines parameter; the V/R ratio of Fe II 5316 (left) and modes of the Hβ single emission peak (right).

variations are monoperiodic in the 1997 season, but biperiodic in 1996, that is when the transient period is present in the *lpv* (Štefl et al. 1998). Then the power of the transient period is even stronger than of the photospheric one.

For ten Fe II and three H I lines, we analyzed the modes of the violet and red emission peaks, for Fe II lines additionally the V/R ratio of the emission peaks (see Fig. 1, right).

No significant periodicity can be detected in the modes of the Fe II emission peaks. However, the V/R variability is biperiodic in JD 2 450 102 – 140. The main 1.37 and transient 1.49 d periods have about the same power. 28 CMa is the first Be star for which temporal multiperiodicity of the V/R variability is proved. Also modes of the Hα and Hβ single peak emission show biperiodic variations in 1996.

4. *RV* amplitudes and improved period of the 1.37 d variability

In order to derive the line-to-line amplitude variations, we fitted a sinusoid to the *RV*s for each measured line. We can confirm significant variations of the *RV* semi-amplitude and the systemic velocity both from ion to ion in a given

https://doi.org/10.1017/S0252921100055913 Published online by Cambridge University Press

season and from season to season for a given ion. The amplitudes are lower in all investigated lines in 1997.

To be able to combine RVs from both seasons, we shifted their γ velocities to zero and scaled the amplitude to a common value (20 km/s). Then, for every ion a formal binary solution was computed with the FOTEL code. The ephemeris of the 1.37-day variations was derived using the mean epoch and period of all lines with single periodic variations in 1996-7:

$$T_{\mathrm{RV,max}} = \ (2450099.65 \pm 0.08) + N \times (1.37187 \pm 0.00005)$$

This period agrees with the mean period of Harmanec (1998) within the errors.

5. Conclusions

Transient periodicities are strongly present at times and cannot be neglected in modes of H I absorption and emission lines and in Fe II V/R variations. As the result, variations of H I modes (and line profiles) may temporarily possess a biperiodic nature and, therefore, a different variability pattern than modes of He I lines. Consequently, one should avoid combining modes of He I and H I lines in frequency analyses unless the periodicity character can be checked independently for all data subsets. Due to possible long-term amplitude variations, even the modes of the same line from different seasons cannot be combined without proper scaling. Neglecting the above effects can lead to false detections of multiperiodicity or of long-term changes of the period.

The modes and V/R ratio of emission lines in 28 CMa varied with both a transient and the stable photospheric period in 1996, when an outburst had probably occured just shortly before. In 1997, the transient periodicity had disappeared and even the photospheric period could not be determined unambiguously. The evolution of the transient periodicity in emission lines of 28 CMa resembles that of μ Cen after outbursts (Rivinius et al., 1998), but the time scale for 28 CMa is much longer. This fact may be consistent with a longer separation of outbursts seen in 28 CMa by Hipparcos (220 or 330 days vs. 20-30 days in μ Cen; Hubert and Floquet, 1998)

References

Baade, D. 1982a, A&A 105, 65

Baade, D. 1982b, A&A 110, L15

Balona, L.A., Aerts, C., Štefl, S. 1999, MNRAS 305, 519

Harmanec, P. 1998, A&A 334, 558

Hubert, A.M., Floquet, M. 1998, A&A 335, 565

Rivinius, Th., Baade, D., Štefl, S., et al. 1998, A&A 333, 125

Štefl, S., Baade, D., Rivinius, Th., et al. 1998, in: *A Half Century of Stellar Pulsation Interpretation: A Tribute to Arthur N. Cox*, eds. P.A. Bradley and J.A. Guzik, Astr. Soc. Pacific Conf. Series 135, 348

Štefl, S., Aerts, C., Balona, L.A. 1999, MNRAS 305, 505

Townsend, R.H.D. 1997, MNRAS 284, 83