Inside the Stars, IAU Colloquium 137
ASP Conference Series, Vol. 40, 1993
Werner W. Weiss and Annie Baglin (eds.)

PHOTOMETRIC DETECTION OF LOW–ORDER NRP IN Be STARS

K. PAVLOVSKI, Ž. RUŽIĆ and V. VUJNOVIĆ
Hvar Observatory, Zagreb University, Kačićeva 26, 41000 Zagreb, Croatia

ABSTRACT Period analysis of Be stars 28 Cyg and EW Lac has shown that their photometric variations are multiperiodic. Dominant periods have counterpart in low–order NRP modes identified in the independent line profile studies.

INTRODUCTION

Be stars are early–type stars with the emission lines in spectra which are produced in an extended circumstellar envelope. The emission line profiles are variable on different time scales, ranging from hours to decades. The emission sometimes disappears completely, producing a normal B-type spectrum. Shell spectrum could be developed on some occasions characterized by narrow and deep absorption cores in the Balmer lines and singly ionized metal lines.

Systematic photometric observations have shown that large fraction of the Be stars are light variables. Most of them are found to be short–term variables, with periodicity around 1 day.

Many models were hypothesized to explain origin of emission lines, i.e. extended envelopes around these stars, and also their variable nature. The most promising at the moment are non–radial pulsations (NRP) which can force variable mass outflow and change considerably the optical depth of the envelope.

NRP: PHOTOMETRIC DETECTION

Spectroscopic diagnostics of the NRP in the Be stars are based on the line profile studies. Both low–order and high–order NRP modes are revealed (Walker 1991).

In photometry detection of NRP is not unambiguous. Namely, periods of light variations found are close to what is expected for rotational modulation (Cuypers 1991). Hence, our detection of NRP is based on the following considerations:

1. Identification of the spectroscopic periods in photometric data
2. Multiperiodicity which is expected in the case of NRP
3. Wavelength dependence of light amplitudes

We concentrated on 28 Cyg and EW Lac, two Be stars for which large data bases, both spectroscopic and photometric, exist at the Hvar Obs. and elsewhere. Particularly intensively observed was 28 Cyg over last few years in satellite UV and ground–based optical region. In a periodogram analysis we isolated the

dominant frequency (period). In extensive photometry of 28 Cyg carried out in the summer 1985 at the Hvar Obs. we found a dominant frequency $f_{ph} = 1.54$ c/d (Fig. 1). This confirmes our previous finding on shorter data set (Pavlovski & Ružić 1990). These results agrees perfectly with the period of low–order NRP mode $l = 2$ found in line–profile analysis by Peters & Penrod (1988) and Hahula & Gies (1991), $f_{sp} = 1.55$ c/d.

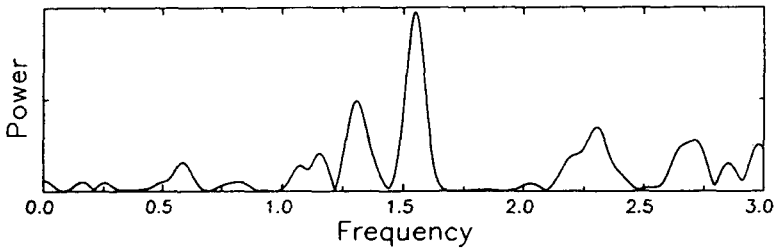

Fig. 1. CLEANed Fourier power spectrum of the B–band light variations of 28 Cyg in 1985 Hvar observations. Two prominent peaks remained on the frequencies $f_1 = 1.55$ c/d and $f_2 = 1.30$ c/d. The former peak corresponds to period of the low–order $l = 2$ NRP mode identified in line–profile studies.

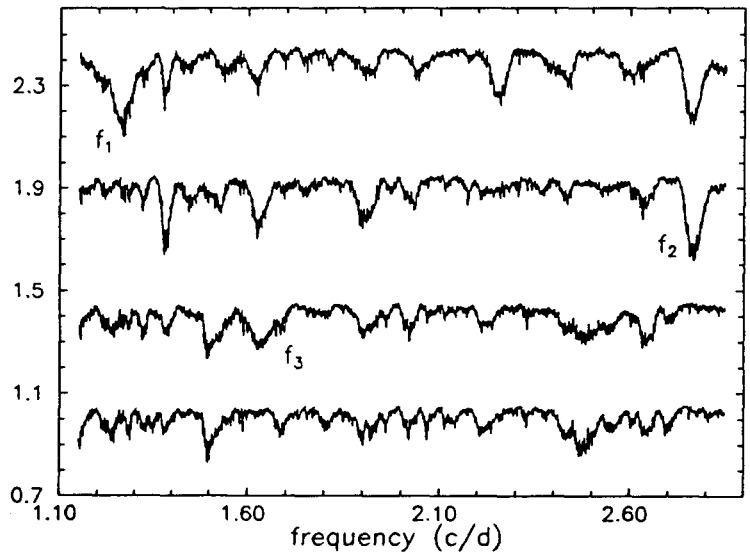

Fig. 2. PDM θ–statistics for the multisite world–wide V passband observations of the Be star EW Lac in 1983, for subsequent steps of prewhitening. Following frequencies are identified: $f_1 = 1.28$ c/d, $f_2 = 2.79$ c/d, and $f_3 = 1.62$ c/d (Pavlovski et al. 1992).

However, successive prewhitening and/or CLEANing show that additional significant frequencies are present and we performed non-linear least-square fitting which support multiperiodicity. Obviously, light amplitudes in V and B passbands are similar, with a larger amplitude in the U passband in agreement

https://doi.org/10.1017/S0252921100018716 Published online by Cambridge University Press

with theoretical calculations (Watson 1988).

Our recent reanalysis of the multisite observations of EW Lac in 1983 (Pavlovski et al. 1992) confirmed previously claimed multiperiodicity (Pavlovski 1987). Further analysis of photometric observations in separate seasons has revealed a correlation between pulsational amplitudes and variable shell activity (Pavlovski & Ružić 1991). Photometric periods are recently confirmed from detail investigation of changes in He I λ6678 line by Floquet et al. (1991, 1992).

A PULSATION MECHANISM

While discussing a possible pulsation mechanism, it would be interesting to notice close similarities of the multiperiodic characteristics for the Be stars 28 Cyg and EW Lac, and *Slowly Pulsating B Stars*, group of B-type variables found and coined by Waelkens (1991).

In an analysis of extensive observational data accumulated at ESO over years, Waelkens found that most of the stars in his sample are multiperiodic. He further argued that these stars pulsate in high-radial low-order g-modes. His conclusion is based on not yet published calculations by Degryse. Having applied her calculations as communicated by Waelkens (1991) to the periods found by us for the Be stars, the models point toward medium radial wavenumbers ($k \sim 10$ for $l = 1$ and $k \sim 20$ for $l = 2$). It should be interesting to work out which physical parameter(s) differenciate(s) the non-emission *slowly pulsating* B stars from pulsating *Be* stars.

REFERENCES

Cuypers, J. 1991, in *Proc. Workshop on Rapid Variability of OB Stars: Nature and Diagnostic Value* , ed D. Baade, ESO Conf. Proc. 36, p. 83.

Floquet, M., Hubert, A. M., Hubert, H. 1991, in *Proc. Workshop on Rapid Variability of OB Stars: Nature and Diagnostic Value* , ed D. Baade, ESO Conf. Proc. 36, p. 39.

Floquet, M., Hubert, A. M., Janot-Pacheco, E., Mekkas, A., Hubert, H., Leister, N. V. 1992, *Astr. Ap.*, (in press).

Hahula, M. E., Gies, D. R. 1991, *Bull. A.A.S.*, **23**, 1379.

Pavlovski, K. 1987, *Ap. Space Sci.*, **134**, 317.

Pavlovski, K., Ružić, Ž. 1990, *Astr. Ap.*, **236**, 393.

Pavlovski, K., Ružić, Ž. 1991, in *Proc. Workshop on Rapid Variability of OB Stars: Nature and Diagnostic Value* , ed D. Baade, ESO Conf. Proc. 36, p. 191.

Pavlovski, K., Ružić, Ž., Pavlović, M., Jeong, J. J., Nha, I.-S. 1992, *Ap. Space Sci.*, (in press).

Peters, G. J., Penrod, G. D. 1988, in *Decade of UV Astronomy with IUE*, ESA SP-281, Vol. 2, p. 117.

Waelkens, C. 1991, *Astr. Ap.*, **246**, 453.

Walker, G. A. H. 1991, in *Proc. Workshop on Rapid Variability of OB Stars: Nature and Diagnostic Value* , ed D. Baade, ESO Conf. Proc. 36, p. 27.

Watson, R. D. 1988, *Ap. Space Sci.*, **140**, 255.