SHORT-PERIOD VARIABILITY OF THE Be STAR λ Eri

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Abstract: Photoelectric and spectrographic observations of the Be star λ Eri made during five nights indicate that the luminosity variations have a different periodicity from that of radial velocity variations. This result seems to show that, at least during our observing time, the observed variability has not to be ascribed to a pulsation of the star.

1. Introduction

Short-period variability in Be stars has been observed by several authors: Spear *et al.* (1981) in 28 Cyg; Bolton (1981) in λ Eri; Baade (1982) in 28 CMa; Hilditch *et al.* (1982) in EM Cep; Percy (1983) in HR 9070 (see also Percy, 1982; Baade, 1983). Several hypothesis have been proposed to explain the variability, and, in particular, it seems that nonradial pulsation is responsible for the observed variations.

The Be star λ Eri (HD 33328, $m_V = 4.27$, B2 IV) has been observed intensively by Bolton (1981) from 1976 to 1980, and he has interpreted his observations in terms of nonradial pulsations. In particular, it seems that the pulsational behaviour is related to the Be activity, in the sense that the pulsational amplitude is low when the star does not show emissions.

This interesting hypothesis must be confirmed by other observations, in order to understand the interaction between pulsation and the ejected envelopes in Be stars. In the present paper we report the results of our observations of λ Eri made during a quiescence phase of the activity of the star.

2. Observations and Reductions

We have made simultaneous spectrographic and photoelectric observations of λ Eri at the Merate Observatory during five nights at the end of 1980. We have obtained thirty-eight spectra with the Boller and Chivens spectrograph of the 1.37 m reflector, on baked IIaO plates; the dispersion was of 35 Å mm^{-1}, and the mean exposure time of 9 min. The spectrograms show very broad spectral lines (from Hβ to H_{10}). Three spectrograms taken on baked 098-04 plates show the broad Hα line without emission and similar to the other hydrogen lines. For radial velocity (RV) determination, the spectrograms were measured with the visual digitized comparator of the Merate Observatory, supplied with an Heidenhain grating (1μ accuracy). The RV data reported in Table I are the weighted means of the velocities computed through the hydrogen lines from Hβ to H_{10} and the He I lines λ 4471, 4387, 4143, 4120, 4026, 4009, and 3819. The error on each RV value is high because of the difficulty of measuring the spectral lines of this high rotational velocity star ($V \sin i = 328$ km s^{-1}). Nevertheless the data plotted in Figure 1 show a trend on a time scale of several hours.

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TABLE I

λ Eri: radial velocity data

JD 2444000.+	km s^{-1} RV	σ	JD 2444000.+	km s^{-1} RV	σ
596.398	−32.3	±10.4	601.398	− 3.1	10.3
.410	− 5.6	6.2	.410	− 9.0	8.0
.418	−28.1	10.5	.422	8.1	3.7
.445	−12.5	10.6	.461	− 9.3	6.1
			.473	−22.7	9.6
597.434	1.1	5.3	.484	−14.1	10.0
.441	−18.1	6.7	.496	− 2.0	5.2
.449	− 7.3	5.7	.504	−17.5	11.5
.457	0.7	7.8	.512	−23.8	9.1
.469	13.8	7.0			
.480	28.4	8.6	602.383	3.1	9.1
.492	−19.1	10.7	.410	4.6	6.3
.500	10.1	8.9	.426	6.6	11.3
.512	−12.3	5.2	.441	9.3	5.7
.523	− 3.0	7.6	.453	− 5.3	6.8
.535	− 0.9	6.1	.469	28.8	9.2
			.492	19.4	7.4
601.355	13.1	7.1	.516	10.9	10.8
.363	5.7	7.7	.531	− 1.8	8.3
.379	2.4	12.9	.547	− 6.8	9.2
.387	−14.0	9.0			

Photoelectric observations were made at the 1.02 m reflector using a standard, B filter a Lallemand photomultiplier and a Weitbrecht-Gardiner amplifier with the integration time set at 15 s. The comparison and the check stars were HR 1671 (CF) and GC 6266 (CK), respectively. The CK was measured with the same frequency as the variable star, in order to evaluate the precision of our measurements. The measurements, corrected for the differential extinction, were arranged into normal points, each one consisting of a different number of observations, in order to achieve an optimum compromise between internal scatter and temporal resolution. The r.m.s. scatter of the (CF–CK) normal points is ±0.0050.

The results of the observations are reported in Tables I, II, and Figure 1. We can see that the amplitude of the RV variations is about 30 km s^{-1}, while that of the light variations (ΔB) is about 0.02 mag.

3. Data Analysis

3.1. Power spectra

Both sets of data were analysed for the search of periodicities by means of the least-squares power spectrum method first proposed by Vaníček (1971). The frequency interval was from 0 to 10 cycles/day (c/d) with a step of 0.005 c/d. The

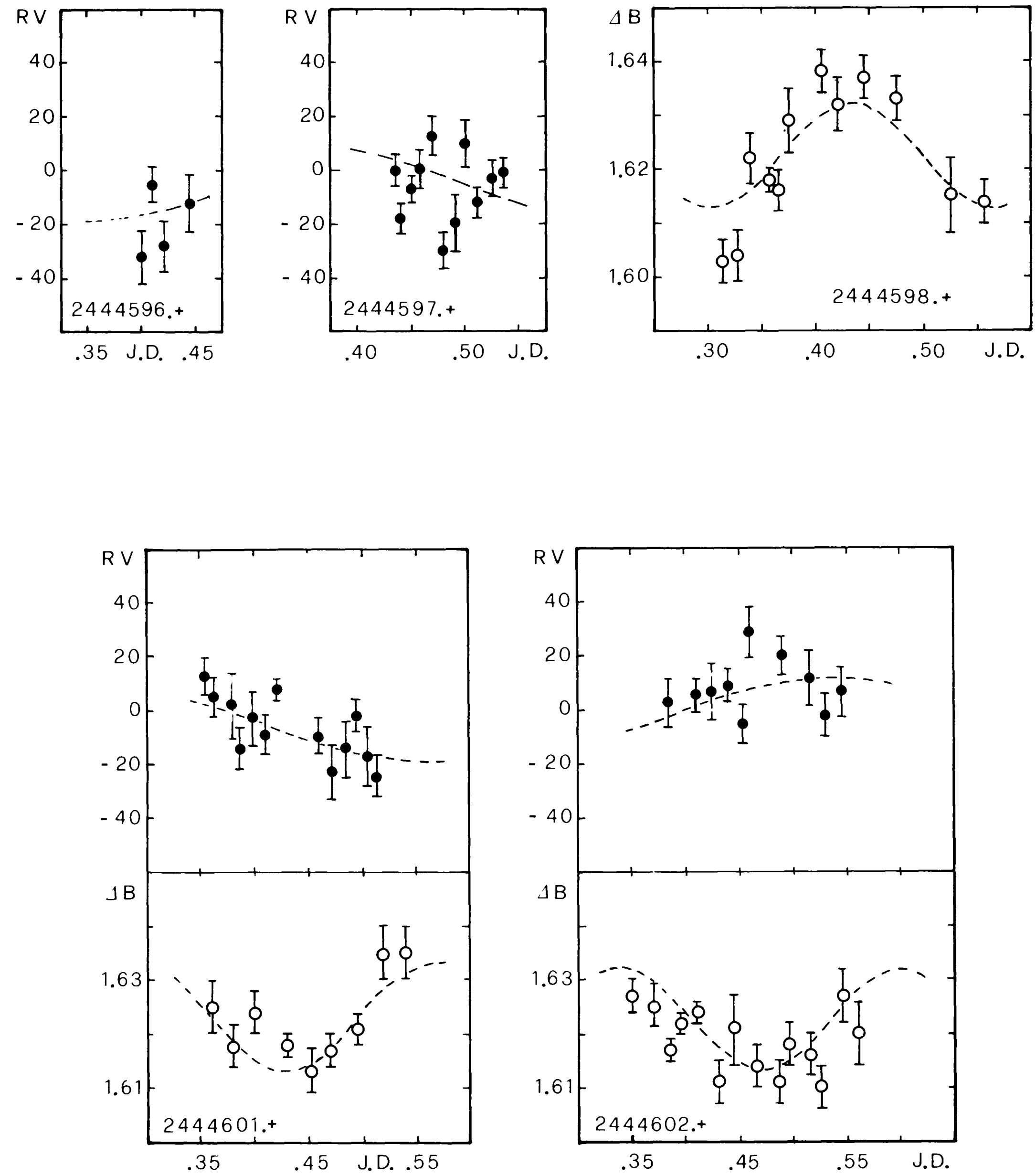

Fig. 1. Radial velocity and photometric observations of λ Eri; the dashed lines are the best solutions of the frequency analysis.

two power spectra are represented in Figure 2 (top: ΔB data; bottom: RV data; the ordinates are the fractional reduction of variance).

The two spectra look very different: the low frequencies dominate in the RV spectrum, while the intermediate frequencies dominate in the photometric one. Because of its small amplitude, in both sets of data the signal is heavily contaminated by the noise. If we assume that the signal is purely sinusoidal, the best frequency for ΔB data is 3.84 c/d with a semi-amplitude of 0.010 mag. and a r.m.s. residual of 0.0053 mag., which is only slightly greater than the scatter of the

TABLE II

λ Eri: photometric data

JD 2444000.+	ΔB	σ	JD 2444000.+	ΔB	σ
598.314	1.603	±0.004	601.518	1.635	±0.005
.327	.604	.005	.538	.635	.005
.337	.622	.005			
.357	.618	.002	602.350	.627	.003
.365	.616	.004	.370	.625	.004
.375	.629	.006	.383	.617	.002
.403	.638	.004	.395	.622	.002
.423	.632	.005	.412	.624	.002
.444	.637	.004	.432	.611	.004
.473	.633	.004	.444	.621	.007
.527	.615	.007	.464	.614	.004
.556	.613	.004	.485	.611	.004
			.497	.618	.004
601.359	.625	.005	.516	.616	.004
.380	.618	.004	.525	.610	.004
.399	.624	.004	.545	.627	.005
.431	.618	.002	.559	.620	.006
.452	.613	.004			
.472	.617	.003			
.497	.621	.003			

(CK–CF) data. The frequency of 3.84 c/d gives a period of 0.26 d, which is comparable to the observational time of each night; hence, a suspicion might arise that this period could be produced by some observational effect. We can exclude this by the following reasons:

(a) the differential extinction between CF and the variable (Var) is comparable to that between CF and CK; hence, a bad evaluation of the extinction coefficient might introduce the same effect on both sets of data; but in the spectrum of the (CF–CK) data there is not any significant peak in the same frequency region of the (CF–Var) spectrum;

(b) the colour difference between Var and CF gives some contribution to the differences between their observed magnitudes; however, the difference between these contributions is at most of about 0.002 mag.;

(c) the trend of the (CF–Var) data in the night 2444598 is opposite to that in the other two nights;

(d) the spectrum of the (CF–CK) data has not any significant peak.

For the RV data, the matter is more complex because in the spectrum there are at least four peaks of comparable hight. They are reciprocal aliases whose relative amplitudes have been alterated by the noise. In order to choose the right frequency of the signal, we attempted to use all the information contained in the spectral pattern rather than only the one contained in each single peak. That is, for each of

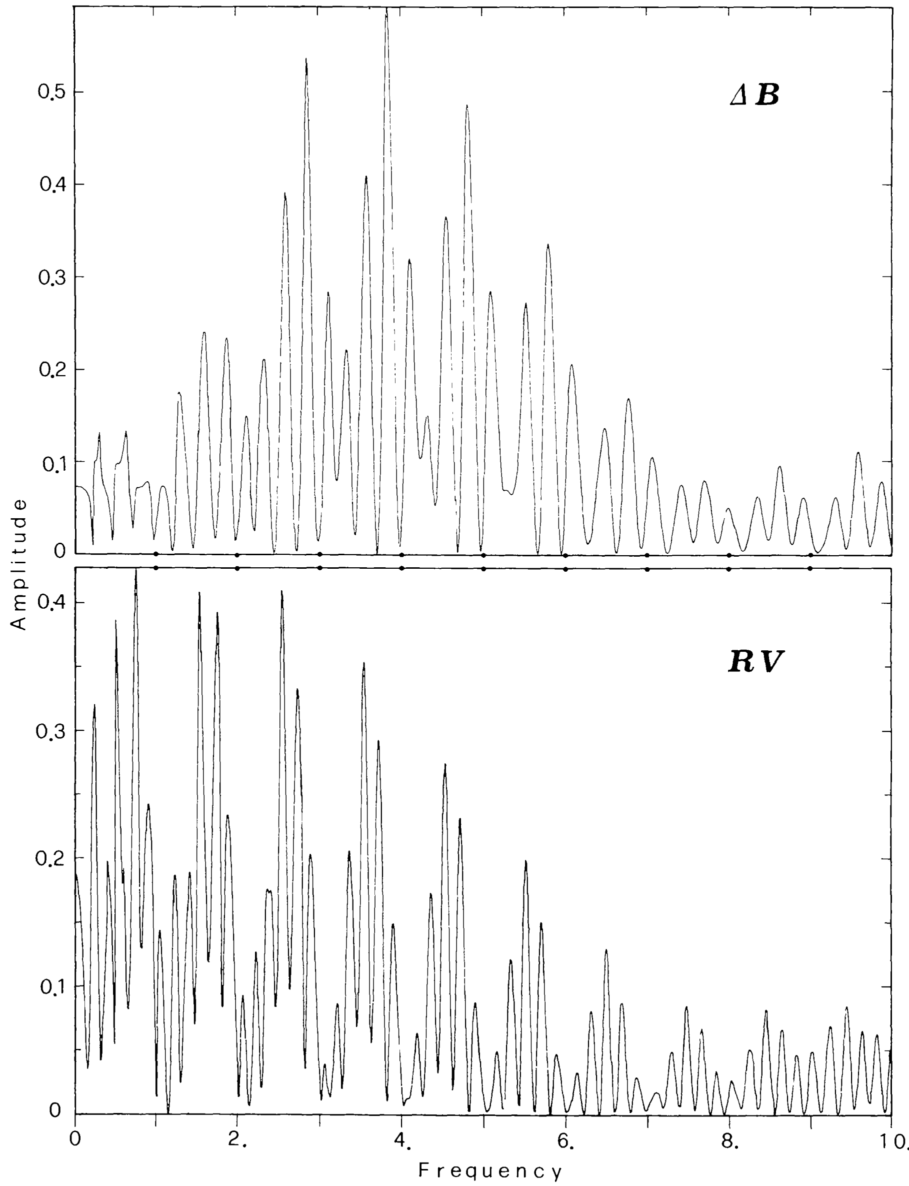

Fig. 2. Power spectra of the photometric (top) and radial velocity (bottom) data.

the four impeached peaks, the least-squares sinusoid which best fitted the data was computed and then sampled with the times of observations. The spectrum of these synthetic data was computed and then compared with the original spectrum (for low frequency spectra, this technique is superior to that of comparing the spectrum with its spectral window; see also Ponman, 1981). As a result, the best choice is the frequency of 1.53 c/d ($P = 0.65$ d); the semi-amplitude is of 15 km s^{-1} and the r.m.s. residual of 10 km s^{-1}. From a statistical point of view (Stobie *et al.*, 1977) we can see that the probability that the two quoted peaks are due to random noise is less than 0.0025 for the ΔB data and less than 0.03 for the RV data (the difference may be ascribed mainly to the different signal to noise S/N ratios: 3 dB for ΔB and 0.5 dB for RV data, respectively).

3.2. Cross spectrum

In order to check the possibility that ΔB and RV variations have the same period (which could be masked by the noise and by the time distribution of the observations), we computed the cross spectrum

$$C(f) = (P_{\Delta B}(f) P_{\mathrm{RV}}(f))^{1/2},$$

where $P_{\Delta B}$ and P_{RV} are the power spectra (auto-spectra) of ΔB and RV data, respectively. It is well known that the auto-spectrum is the convolution of the true spectrum with the spectral window; this is not longer true for the cross spectrum (Deeming, 1975). In any case, if the two time series have not the same time distribution and they *do* contain the same spectral information, we have to expect that in their cross-spectrum the problems due to aliases are alleviated.

The cross-spectrum of the data has a spectral pattern distributed around a main peak near 3.5 c/d. In order to interpret this result, we considered two sinusoidal time series with this frequency and sampled as the ΔB and RV data (the cross-spectrum for these series confirms the reduction of the aliases). Then we added some random noise (with gaussian distribution) to the synthetic series in such a way as to have the same S/N ratios as for the observed series. The peaks in the auto-spectra of the two synthetic time series (with noise) are as high as the peaks in the auto-spectra of the observations; on the other hand, the peaks in the cross-spectrum of the synthetic time series are higher than the peaks in the cross-spectrum of the observations. This result gives further evidence that the time series of ΔB and RV data have not the same period.

4. Discussion and Conclusion

In his preliminary paper on λ Eri, Bolton (1981) reports that a period of 0.7015 d fits satisfactorily his spectrographic and partial photometric data. Moreover, according also to Percy and Lane (1977), it seems that larger variation amplitudes of RV and ΔB occur during the emission phases of the star. In particular, the RV amplitude varies from less than 30 to 60 km s^{-1}. As the complete work on this subject has not been yet published, we cannot make an accurate comparison of our results with Bolton's ones. However, taking into account the uncertainty of the data and the small number of observations, our RV period and amplitude are consistent with the published period and amplitude. As regards the photometric data, our results are quite different, since we find a period of 0.26 d. This period is similar to that obtained by Balona (1977); however, his observations, made during only one night, do not cover a complete cycle. We have attempted to analyse the photometric observations of Percy (1981) with the same method adopted for our data. First we considered his whole set of data (two seasons), but we did not obtain any clear period; then we analysed separately the data of the two different seasons. The two power spectra have a low frequency appearance with the highest peaks at

1.28 and 0.42 c/d, respectively, but with low significance, as the probability that they can be produced by random noise is about 7.5 and 16%, respectively. Hence, the results of the analysis are not significant.

Recently, we have discussed the possibility that the observed variability is due to nonradial pulsation of the star (Antonello *et al.*, 1983). We think that, for the present, it is difficult to explain the different period and amplitude of RV and ΔB variations in terms of classic nonradial pulsations.

We may not exclude the possibility that the photometric period is actually half of the RV period; in this case, the variations may be due to a geometrical factor rather than to an intrinsic one. Indeed, assuming a radius of 6.3 $R_\odot$ for a B2 IV star (Straizys and Kuriliene, 1981), the rotation period would be 0.95 d for an equatorial velocity $V_e = 328$ km s^{-1}; if the star is not seen equator on, we need $V_e = 450$ km s^{-1} to have a rotation period of 0.7 d.

However, at the present we cannot give a clear interpretation of the observed phenomenon, and other observations need to solve the problem.

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