1982Ap&SS..85...25B

STUDY OF THE VARIABILITY OF THE DELTA SCUTI-STARS

III: *Radial and Nonradial Pulsations in KW 207*

MICHELE BOSSI, GIANANTONIO GUERRERO, LUCIANO MANTEGAZZA, and MARCO SCARDIA

Osservatorio Astronomico di Brera, Merate, Italy

(Received 18 November, 1981)

Abstract. Photoelectric observations of the Delta Scuti star KW 207 (HD 73576) are given. In spite of the low variations, the analysis of the light curves shows at least two sighificant periodicities, which seem to be related to non-radial pulsations.

A third frequency, corresponding to the radial fundamental mode, is probably bame out by our data.

1. Introduction

KW 207 (HD 73576), spectral type A7, is an evolved δ Scuti-star ($\Delta c_1 = 0\overset{m}{.}169$) with high rotational velocity ($v \sin i = 210$ km s^{-1}) (Uesugi *et al.*, 1970). It has been discovered as a δ Scuti-star and observed for one night by Breger (1970), who successively found out a period of $0\overset{d}{.}071$ (Breger, 1972).

We began B photoelectric observations of this star during 1977. For the instrumental equipment and the observational procedure see Bossi *et al.* (1977a). KW 229 (HD 73619) was the comparison star, whose constancy has been verified by means of the check star KW 276 (HD 73711). A previous analysis related to the first four nights of observation has been published in 1977 (Bossi *et al.*, 1977b): we did not find any evidence of the period proposed by Breger. Two successive nights in 1979 and four nights in 1980 augmented our data. The light amplitude does not exceed $0\overset{m}{.}04$.

Table I and Figure 1 show our B normal points with observational times and standard errors σ.

2. Analysis of the Light Curves and Discussion

The data were analyzed with a least-squares method similar to that proposed by Vaniček (1971); see Bossi *et al.* (1981). Because of the large time gaps among the three groups of observations related to 1977, 1979, and 1980, we computed separately the power spectra of each group, weighting the normal points as $1/\sigma^2$. Then we performed a weighted average of three spectra obtaining three periodicities. An analysis of the whole set of the data was limited to the spectral regions around these three frequencies. The results are reported in Table II, where we indicate, for each frequency, the corresponding amplitude, the phase related to $T_0 = 43668.9646$ JD and the percentage reduction of the variance. Because of the large gaps among the three groups of data, it is safer to assume an error in the frequencies of about 0.015 c/d instead of that resulting from the whole time base.

Astrophysics and Space Science **85** (1982) 25–29. 0004–640X/82/0851–0025$00.75.
Copyright © 1982 *by D. Reidel Publishing Co., Dordrecht, Holland, and Boston, U.S.A.*

© Kluwer Academic Publishers • Provided by the NASA Astrophysics Data System

1982Ap&SS..85...25B

TABLE I

Hel. J.D. 2400000+	Δ *B*	σ	*Hel. J.D.* 2400000+	Δ *B*	σ	*Hel. J.D.* 2400000+	Δ *B*	σ
43168.480	−0.079	.004	.422	−0.069	.002	.562	−0.073	.002
.484	−0.069	.004	.430	−0.067	.001	.570	−0.075	.002
.499	−0.060	.002	.438	−0.063	.001	44271.411	−0.085	.005
.503	−0.061	.004	.444	−0.066	.002	.415	−0.080	.004
.513	−0.077	.003	.449	−0.074	.002	.488	−0.052	.004
.517	−0.080	.002	.457	−0.076	.001	.498	−0.059	.003
.529	−0.087	.003	.464	−0.079	.001	.507	−0.071	.001
43173.516	−0.058	.002	.471	−0.079	.002	.513	−0.080	.001
.522	−0.063	.003	.478	−0.075	.002	.519	−0.093	.002
.536	−0.076	.002	.484	−0.070	.002	.524	−0.091	.003
.542	−0.076	.002	.491	−0.062	.002	.529	−0.086	.001
.553	−0.078	.002	.497	−0.062	.001	.534	−0.082	.002
.558	−0.070	.003	.503	−0.068	.002	44295.385	−0.082	.002
.571	−0.063	.002	.509	−0.072	.002	.391	−0.086	.002
.576	−0.067	.002	.515	−0.073	.002	.405	−0.077	.004
.582	−0.072	.001	.522	−0.071	.004	.410	−0.071	.002
.596	−0.079	.003	.528	−0.072	.002	.416	−0.066	.003
.602	−0.079	.003	.534	−0.068	.002	.430	−0.068	.002
.609	−0.073	.002	.541	−0.070	.002	.435	−0.073	.003
.621	−0.060	.004	.548	−0.067	.002	.441	−0.077	.001
.627	−0.065	.003	.555	−0.069	.002	.454	−0.069	.003
.634	−0.066	.003	43886.401	−0.057	.004	.459	−0.069	.003
.645	−0.077	.003	.421	−0.074	.002	.474	−0.063	.002
.652	−0.080	.003	.433	−0.083	.003	.486	−0.079	.004
43174.367	−0.069	.002	.444	−0.073	.002	.492	−0.088	.002
.385	−0.067	.003	.461	−0.062	.001	.505	−0.081	.003
.399	−0.085	.004	.491	−0.084	.002	.511	−0.077	.002
.413	−0.072	.003	43889.391	−0.064	.002	.518	−0.074	.002
43203.314	−0.061	.002	.399	−0.074	.002	.532	−0.071	.004
.322	−0.065	.003	.409	−0.082	.003	.538	−0.071	.003
.325	−0.069	.003	.418	−0.090	.003	.545	−0.069	.002
.330	−0.070	.002	.426	−0.081	.002	.560	−0.076	.002
.336	−0.073	.001	.436	−0.065	.002	.566	−0.064	.003
.342	−0.077	.001	.446	−0.066	.001	.572	−0.073	.007
.347	−0.084	.001	.456	−0.073	.002	44298.445	−0.080	.004
.353	−0.082	.002	.465	−0.075	.001	.451	−0.072	.006
.361	−0.075	.002	.474	−0.077	.002	.457	−0.064	.003
.366	−0.064	.002	.482	−0.071	.002	.468	−0.064	.002
.372	−0.062	.001	.491	−0.065	.001	.473	−0.073	.002
.379	−0.060	.001	.500	−0.069	.001	44302.340	−0.082	.002
.385	−0.065	.002	.510	−0.078	.001	.349	−0.077	.002
.390	−0.069	.001	.519	−0.076	.001	.357	−0.062	.004
.399	−0.078	.002	.529	−0.080	.001	.375	−0.070	.002
.405	−0.082	.002	.537	−0.072	.001	.384	−0.074	.004
.411	−0.079	.001	.546	−0.074	.001			
.417	−0.077	.002	.554	−0.075	.002			

© Kluwer Academic Publishers • Provided by the NASA Astrophysics Data System

1982Ap&SS..85...25B

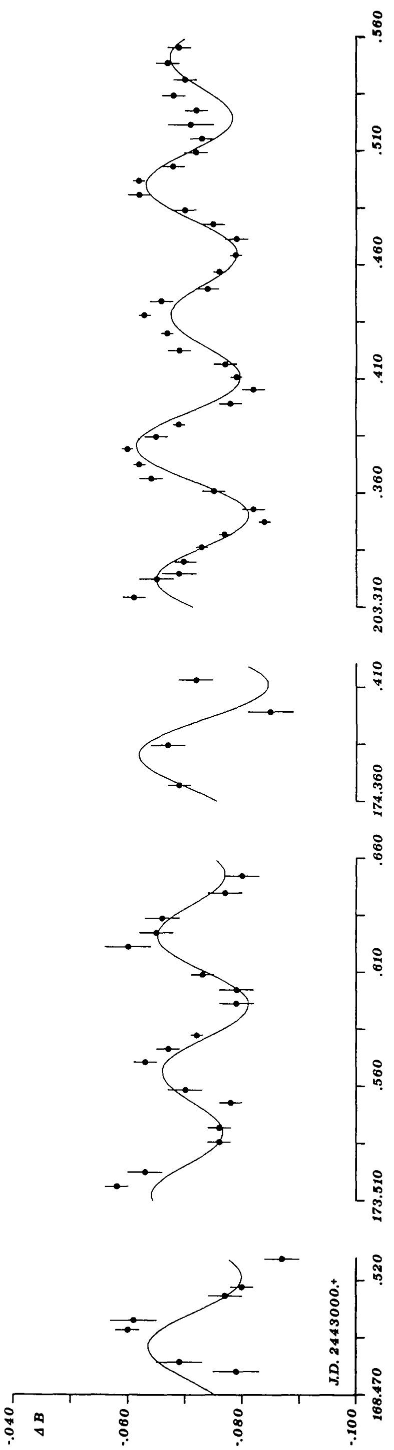

Fig. 1a.

Fig. 1a–c. B normal points and synthesized light curves of KW 207. Bars represent the double standard errors 2σ.

© Kluwer Academic Publishers • Provided by the NASA Astrophysics Data System

1982Ap&SS..85...25B

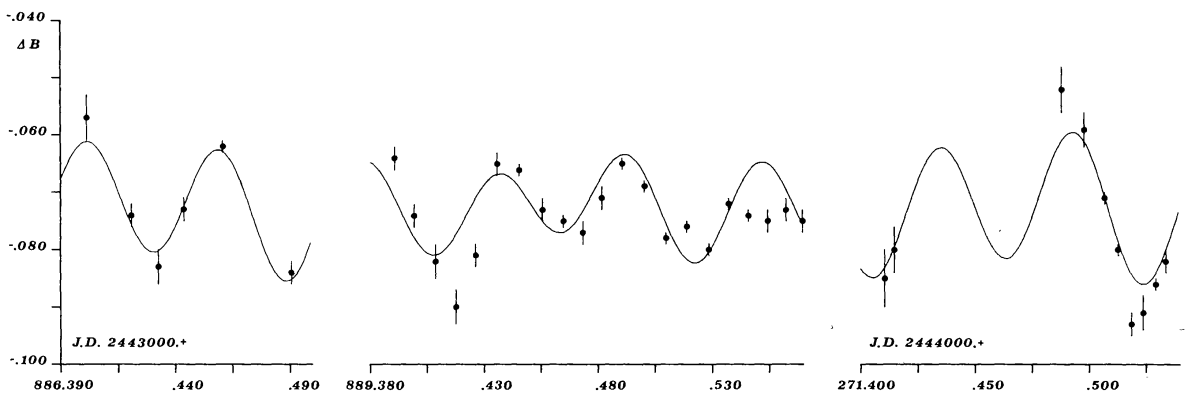

Fig. 1b.

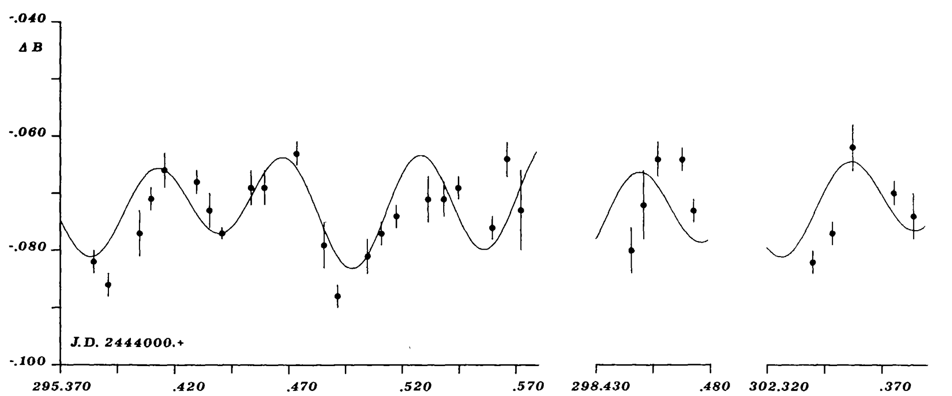

Fig. 1c.

TABLE II.

	P days	Frequencies c/d	Amplitudes mag	Phases	Reduction factors of the variance %
1	0.0583	17.141	0.0091 ± 0.0007	0.359 ± 0.020	65.5
2	0.0642	15.570	0.0038 ± 0.0007	0.834 ± 0.172	34.0
3	0.1175	8.510	0.0024 ± 0.0006	0.774 ± 0.131	21.0

The parameters reported in Table II have been used to draw the synthesized light curves in Figure 1, means of the equation

$$\Delta m(t) = \Delta m_0 + \sum_{i=1}^{3} a_i \sin(2\pi f_i(t - T_0) + \varphi_i).$$

The amplitudes computed separately for each observational period seem to indicate a progressive increase of the pulsational activity from 1977 to 1980. Nevertheless, this fact cannot be considered definitely assured, because of the large errors involved. Therefore we don't take into account this more complex representation, which obviously would give a better fit of the data.

© Kluwer Academic Publishers • Provided by the NASA Astrophysics Data System

1982Ap&SS..85...25B

Certainly P_1 and P_2 are statistically meaningfull, since they overcome a partial *F*-test with 99% of confidence (Buzzi-Ferraris, 1975). The ratio $P_1/P_2 = 0.908$ doesn't agree with the theoretical values calculated for radial pulsations of reasonably low order, while being in excellent agreement with the value (0.916) corresponding to the first and second non-radial *p*-modes (with $l = 4$) for an evolved δ Scuti star (Petersen, 1975). We can support the non-radial nature of P_1 and P_2 evaluating the related pulsation constants. Introducing into the formula (5) of Petersen *et al.* (1972) the physical parameters derived from the *ubvy* β photometry (Hauck *et al.*, 1979), we obtain the values: $Q_1 = 0^{\text{d}}.019$; $Q_2 = 0^{\text{d}}.021$ which are almost identical with these reported in the above quoted paper (Petersen, 1975), for the two lower non-radial modes with $l = 4$.

The reliability of P_3 as a true period is less evident. The corresponding value of the pulsation constant, i.e. $Q_3 = 0^{\text{d}}.038$, obtained with the same method used for Q_1 and Q_2, agrees enough well with the hypothesis of a fundamental radial mode. On the other hand, the *P–L–Te* relation (Gupta, 1978) for the fundamental radial pulsation gives $M_{\text{bol}} = 0^{\text{m}}.97 \pm 0^{\text{m}}.20$ that is very close to the value ($M_{\text{bol}} = 1^{\text{m}}.08$) obtained from the *ubvy* β photometry. Finally we remark that $P_3 \simeq 2P_1$: since P_3 is an allowed period, its excitation due to a resonance interaction with P_1 seems to be a reasonable possibility. Consequently, we think that even the pulsation corresponding to P_3 is probably real.

KW 207 is not the only δ Scuti-star which shows a mixture of radial and non-radial modes of pulsation: such a phenomenon is present also in δ Scuti itself, HD 188136, 1 Mon., HD 116994, etc.

Finally we can remark that the high rotational velocity of KW 207 weakens the hypothesis that among giants the variables have considerably lower rotational velocities than the constant stars (Breger, 1979).

Acknowledgements

We are grateful to Dr E. Antonello for the useful discussions and to Dr P. Paolicchi for his critical reading of the manuscript.

References

Bossi, M., Guerrero, G., and Mantegazza, L.: 1977a, *Astron. Astrophys. Suppl. Ser.* **29,** 327.
Bossi, M., Guerrero, G., and Mantegazza, L.: 1977b, *Inf. Bull. Var. Stars,* No. 1337.
Bossi, M., Guerrero, G., Mantegazza, L., and Scardia, M.: 1981, *Astrophys. Space Sci.* **79,** 463.
Breger, M.: 1970, *Astrophys. J.* **162,** 597.
Breger, M.: 1972, *Astrophys. J.* **176,** 373.
Breger, M.: 1979, *Publ. Astron. Soc. Pacific* **91,** 5.
Buzzi-Ferraris, G.: 1975, *Analisi et identificazione di modelli,* Clup Milano.
Gupta, S. K.: 1978, *Astrophys. Space Sci.* **59,** 85.
Hauck, B. and Mermilliod, M.: 1979, *Astron. Astrophys. Suppl. Ser.* **40,** 1.
Petersen, J. O.: 1975, 'Multiple Periodic Variable Stars', *IAU Colloq.* **29,** 195.
Petersen, J. O. and Jǿrgensen, H. E.: 1972, *Astron. Astrophys.* **17,** 367.
Uesugi, A. and Fukuda, I.: 1970, *Contr. Univ. Kyoto* **189.**
Vaníček, P.: 1971, *Astrophys. Space Sci.* **12,** 10.

© Kluwer Academic Publishers • Provided by the NASA Astrophysics Data System