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Research Note

The Delta Scuti Variable BD +28°1494

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Summary. B and V light curves which show the δ Scuti variability of BD +28°1494 are given. Period analysis of the observations obtained on seven nights in 1978 and 1979 are presented. A beat phenomenon with $P_1/P_0=0.78$ can be seen during one night, one pulsation only with the same value for $P_1=0\overset{d}{.}0553$, but with slightly different amplitudes appears on four nights, whilst on the two remaining nights no significant power appears above the noise level.

Key words: δ Scuti stars – photometry

Observations

During the course of computation for solving the B and V light curves of the binary system GW Gem, obtained at Merate Observatory during the years 1978 and 1979, the comparison star BD +28°1494 (=SAO 079766) appeared to be variable. The residuals from the computed light curves relevant to the observations obtained during several nights indicate a δ-Scuti-like variability (Broglia and Conconi, 1979). The analysis of the differential magnitudes between BD +28°1494 and the check star BD +27°1497 (=SAO 079761) confirmed the variability of the comparison star. Because of scanty number of check star measurements, 110 B or V measurements altogether, it was not possible to compare GW Gem with BD +27°1497 and the brightness variations of the eclipsing system appeared convoluted with those of BD +28°1494. We were able however to derive a substantial set of elements for GW Gem ($P=0\overset{d}{.}65944$) because:

a) the δ Scuti effect is small compared with the eclipse variations and it was possible to remove it from the larger part of the measurements.

b) the light curve of GW Gem appeared to be stable and devoid of sensible perturbations.

The solutions calculated for the binary system have been given elsewhere (Broglia and Conconi, 1981). Moreover for BD +28°1494 we obtained: $V=9\overset{m}{.}32$, $B-V=+0\overset{m}{.}21$. In this note we report in detail on the variability of BD +28°1494.

Period Analysis

The data sets analysed are over two time spans, one of 26 d, the other of 50 d, separated by one year. In order to divide the δ Scuti component from the eclipse variations a light curve representing a preliminary set of photometric elements (which later on appeared to agree substantially with the final ones) was subtracted from single observations. From inspection of the plot of the residuals it was evident that:

a) the light curves can exhibit oscillations of changing amplitude clearly indicating a beat phenomenon with a range slightly smaller for V measurements.

b) the total light range can reach $0\overset{m}{.}035$ at the most, but it is generally smaller and the variations can merge into the noise. This of course does not mean that no variation occurs, but only that, if present, it is below the detection threshold for the night.

This difficult situation compelled us to restrict the analysis only to the larger sets of measurements, encompassing some oscillations; however about three-quarters of the material was considered. These nightly sequences of residuals of single observations from computed light curves are plotted in Fig. 1. The analysis was performed separately for every single night and colour. In an attempt to determine the values of the periods we have assumed the light curves can be represented by two sinusoids

Table 1. Results of periodogram analysis

JD 2443...		P_1	P_0	σ	σ_1	σ_0	A_1		A_0	
543	V			7.7						
	B			7.9						
544	V	$0\overset{d}{.}0538$	$0\overset{d}{.}075$	7.6	6.4	6.1	5.6	±1.1	3.1	±1.1
	B	0.0552		8.8	6.6		8.8	1.1		
577	V	0.0575		8.2	7.3		5.3	1.4		
	B	0.0588	0.091	9.2	7.8	7.1	7.2	1.5	4.3	1.5
876	V	0.0676		10.4	8.7		8.0	1.5		
	B	0.0633		11.2	9.7		8.2	1.7		
903	V	0.0571		9.3	6.7		9.1	1.6		
	B	0.0521		9.4	6.9		8.9	1.7		
905	V	0.0538	0.069	9.2	7.5	6.8	7.7	1.0	4.2	1.0
	B	0.0543	0.070	11.9	8.1	6.5	11.8	0.9	6.5	0.9
926	V			6.7						
	B			9.1						

σ, σ_1, σ_0 are the rms residuals of individual observations, expressed in m · mag, before and after a simple or a double sinusoid have been fitted to the measurements. The amplitudes A_1 and A_0 of sinusoids with periods P_1 and P_0 and the corresponding mean errors are also given in m · mag

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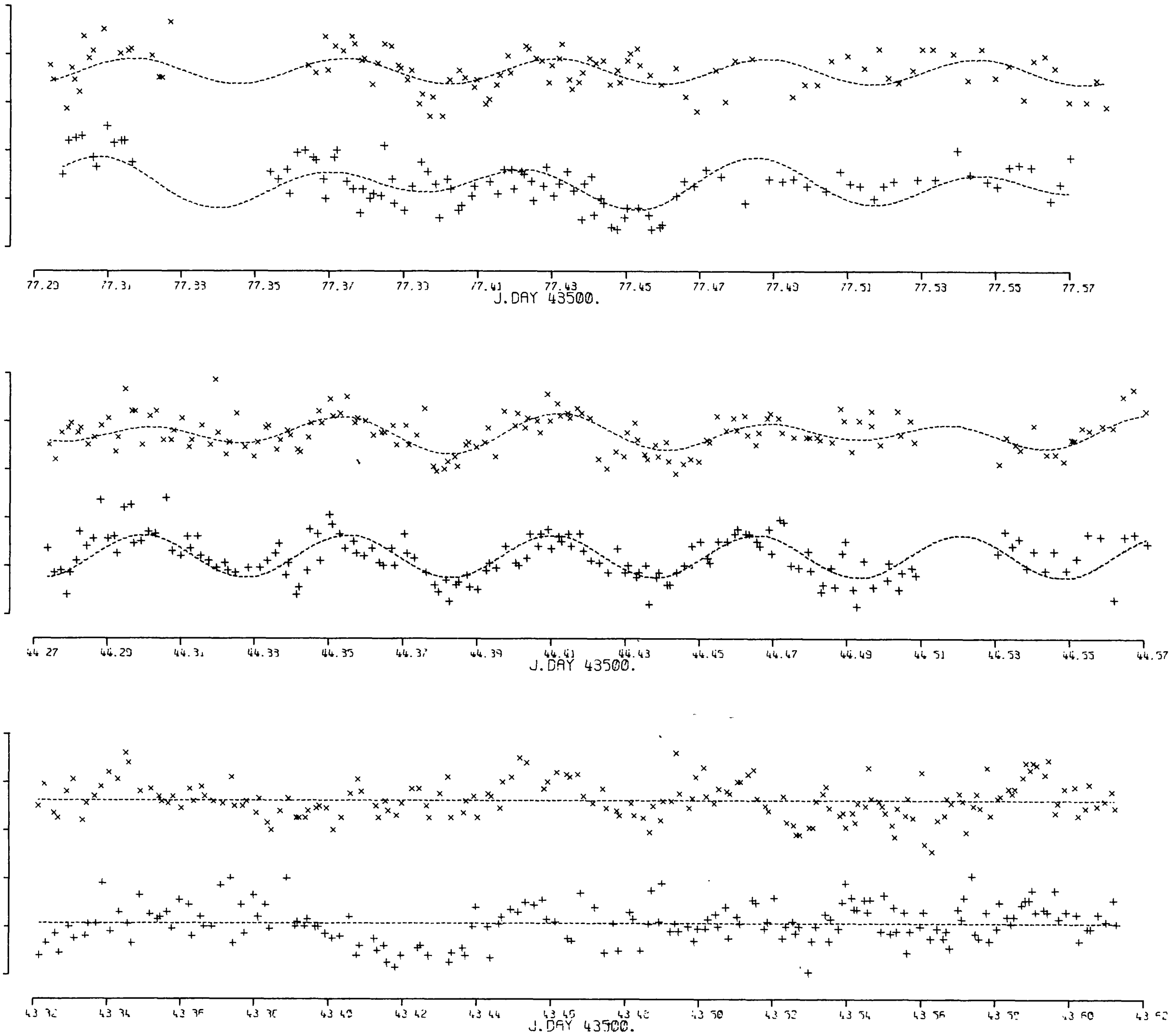

Fig. 1. Individual differential magnitudes between BD +28°1494 and GW Gem, cleared from the eclipse effects of the binary star GW Gem. The curves calculated with the values given in Table 1 are plotted through the observations. The ordinate marks are spaced 0.02 mag. V observations above

according to the equation:

$$m = m_0 + A_0 \sin\left(\frac{2\pi}{P_0}(t-t_0)\right) + A_1 \sin\left(\frac{2\pi}{P_1}(t-t_0)\right) \qquad (1)$$

where m_0 is the mean light level, A_0, A_1, P_0, P_1 are the amplitudes and the periods of oscillations and T_0, T_1 the dates of their zeros. The method of fitting sinusoids by least squares to measurements was used. The frequency domain explored was between 25 and 7 c/d with a step of 0.2 c/d. For each period the reduction factor in scatter $R=(S-S_P)/S$ was derived, where S and S_P are the sums of squares of residuals respectively before and after the fitting of the sine curve to the residuals. To the largest value of R corresponds the dominant period P_1 that was sought. The observations then were analysed again to find the next possible period P_0 by fitting the curves (1) to the measurements. Keeping P_1 now fixed, for a convenient set of periods P_0 the amplitudes A_0, A_1 and the dates T_0, T_1 were adjusted by least squares and the corresponding reduction factors were evaluated. For all sets of observations it was sufficient to stop the analysis at P_0 at the most. The results of Fourier analysis are reported in Table 1 and the best fitting curves are drawn in Fig. 1.

The differential magnitudes between BD +28°1494 and the check star BD +27°1497 were analysed analogously to check that neither of the components of GW Gem is an intrinsic variable. The observations obtained during JD 43903 and JD 43905 are plotted in Fig. 2 and confirm the variability of BD +28°1494.

Discussion

The rich morphology of photometric behaviour for the δ Scuti variables is well known (Breger, 1979). Beat phenomena can occur, the periods can be stable over time span of years or several weeks only or they can also change from night to night. The amplitude of light variation often changes and can get as small as the noise level so it is difficult to assert that the star is still pulsating.

Let us now consider the results of the analysis given in Table 1 and Fig. 1. The two seven-hour sets on consecutive nights JD 543

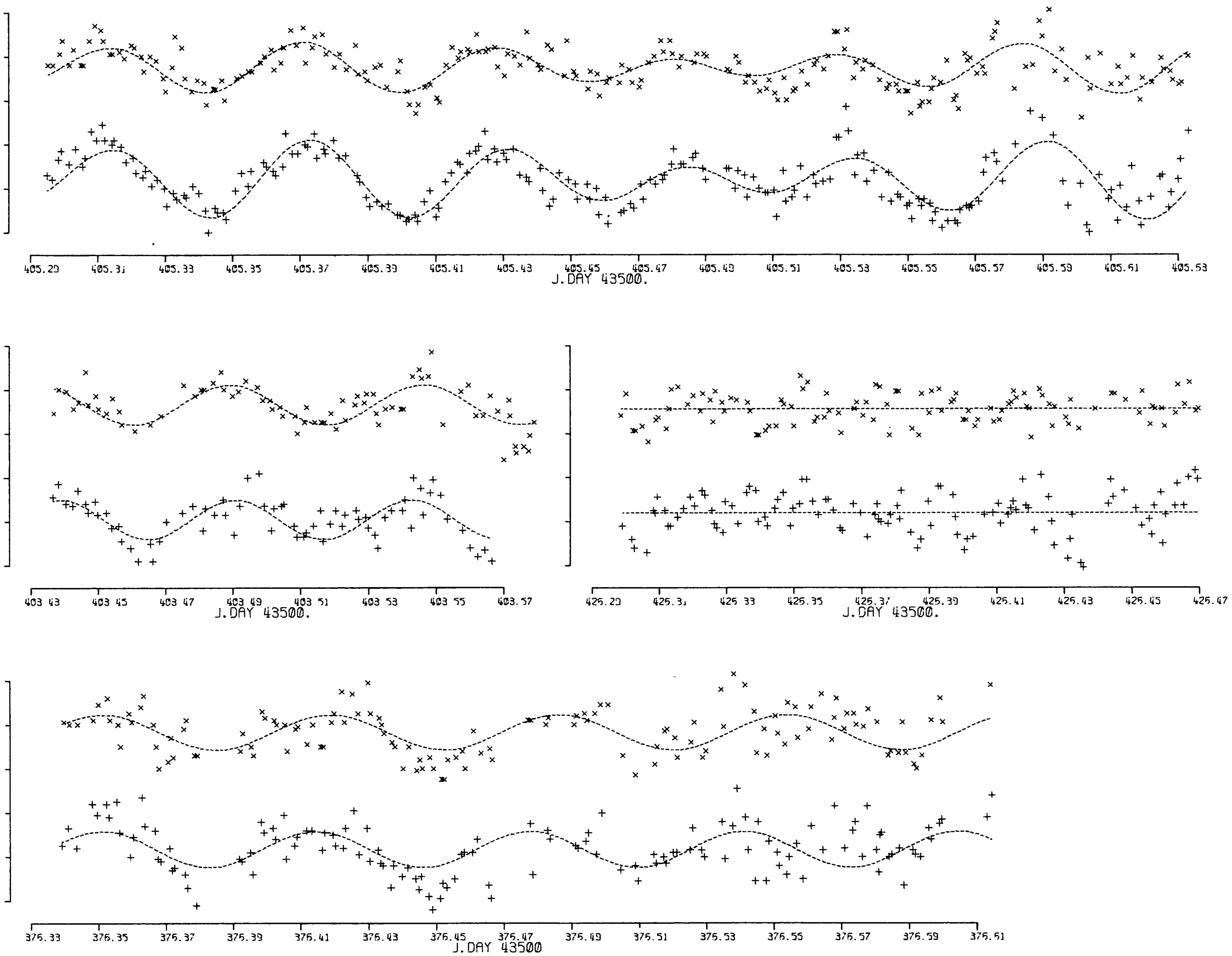

Fig. 1 (continued)

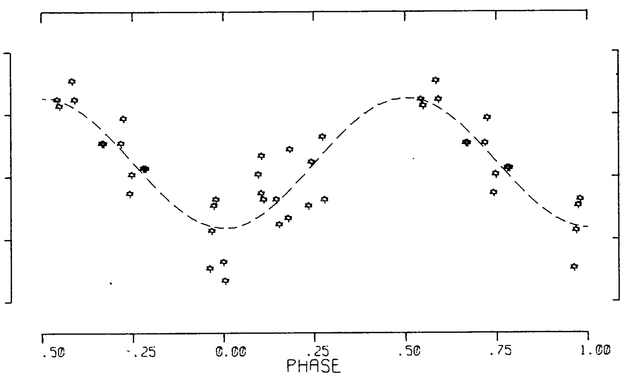

Fig. 2. Differential magnitudes between BD +28°1494 and BD +27°1497 for JD 43903 and JD 43905, brought in phase using the period $P_1 = 0.0553$ d calculated from these observations. The B measures are shifted vertically in relation to the V ones to have the same fitting sinusoid. The subtraction of the sinus-component reduces the mean error of a single measurement from 0.008 to 0.005 mag. The ordinate marks are spaced 0.01 mag

and JD 544 show a different situation. During the first night the noise is dominant and at most we can guess feeble indications of an incipient oscillation, but not coherent in both colours, whilst a few hours later one period is clearly dominant and a weak sign of a surging beat phenomenon also appears, but in the V light-curve only. Some weeks later, during JD 577, some traces of beat phenomenon can still be seen, but now in the B band. During the following year the same dominant pulsation is evident and in a two days' interval (from JD 903 to JD 905) a strong modulation rises with a total range of $0^{m}.035$ at most, but three weeks later no pulsation can any more be detected.

Because it is unlikely that a pulsation rises in one colour only or that a dephasing between B and V light curves increases during a night, periodograms have been obtained by stacking together the B and V periodograms for each night to reduce the influence of the noise (Fig. 3). The plot shows clearly that the variable may sometimes have a very small pulsational activity but, if it exists it is below the noise level of our observations. Afterwards a pulsation with a well-defined period P_1 becomes evident. Disregarding the value pertinent to JD 876, when the noise is slightly stronger than usual, as it appears when inspecting the

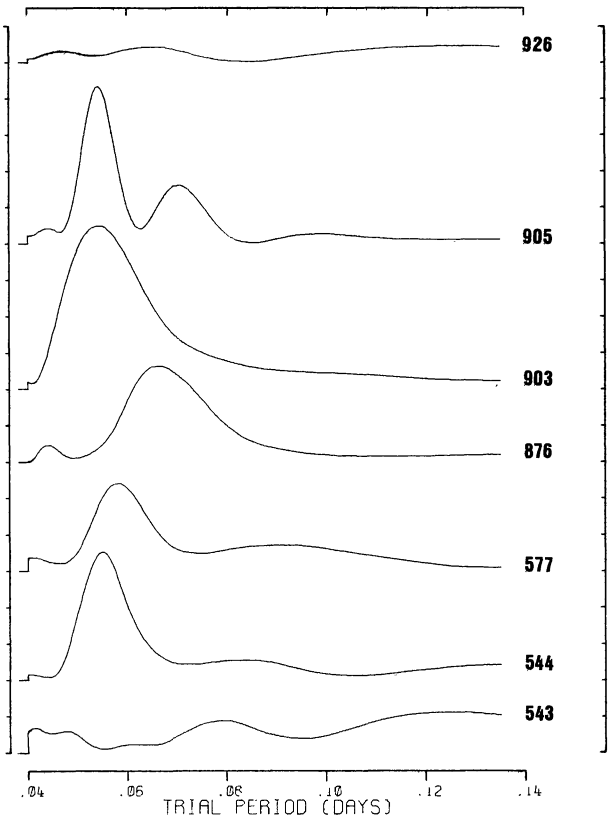

Fig. 3. Periodograms covering the range from 0.04 to 0.14 d, obtained stacking the B and V periodograms for individual nights. The space between consecutive marks indicates a ten-per-cent variation in the reduction factor R (see text). The Julian Date of each curve is JD 2444000+ the number next to the curve

plots, we find the mean value $P_1 = 0\overset{d}{.}0553 \pm 0\overset{d}{.}0008$ m.e. This period persists over one year span. When the activity becomes stronger a second pulsation rises with $P_0 = 0\overset{d}{.}070$ and a slightly smaller amplitude. Because the r.m.s. residuals from Eq. (1) of individual observations are the same as when no pulsation can be detected we can conclude that there are probably no remaining periodicities in the light curves.

The ratio $P_1/P_0 = 0.78$ pertaining to JD 905 is close to the values ascribed for pulsators in fundamental and first overtone modes. The changes of the energy in fundamental and first overtone modes, so rapid in comparison with the 10^4 yr calculated as rising time of the pulsation in a δ Scuti star (Chevalier, 1971) in our opinion do not indicate non-linearities effects in the atmosphere because the period P_1, when excited, has the same value and the ratio P_1/P_0 is normal for radial pulsators, but only that the pulsation status in the star is not yet firmly assessed or decaded. If possible the instability can be related to the fact that, on account of the temperature $T = 7760$ °K being derived from the colour, the variable is close to the line $T = 7800$ °K in the diagram $M_V - T_e$, where according to Breger and Bregman (1975) fundamental pulsators separate from overtone pulsators.

On account of the moderate number of observations and their distribution in time it is rash to make evaluations about the course of intervals of different pulsational activity, which anyway is very rapid because changes can occur from one night to the next. New observations should be useful to find out more about these points as our measurements were planned in order to derive a good coverage of the eclipse variations of GW Gem.

The observations have been deposited in the IAU Commission 27 Archives as file number RAS-76.

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