LIGHT VARIATION OF THE DELTA SCUTI STAR 38 CNC

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(Received March 20, 1979; revised July 11, 1979)

Abstract

The light curves of the δ Scuti variable 38 Cnc, which is a member of the Praesepe cluster, have been analysed using the techniques of periodogram analysis and least square solutions. The star pulsates in the second overtone as well as in the first overtone modes with the periods of $0.^{d}10229$ and $0.^{d}12715$ respectively. The period ratio of the second overtone to first overtone indicates that the star pulsates in the radial mode. The absolute magnitude, derived from the cluster modulus, is $0.^{m}52$. The effective temperature and mass of the star are derived to be nearly 7800°K and 2.2 $M_{\odot}$ respectively.

I. INTRODUCTION

The star 38 Cnc [F_0 III, V = $6^{m}.67$], a member of the Praesepe cluster (Johnson 1952), was first reported as a variable by Breger (1970). Later, based on its period of $0^{d}.110$ and amplitude of light variation of $0^{m}.03$ Breger (1973) assigned this star as a δ Scuti variable. Gupta and Bhatnagar (1974) made observations of one cycle of this star and found a mean period of $0^{d}.108$ and an amplitude variation of $0^{m}.07$. Guerrero (1975), on the basis of his observations over two consecutive nights, had found a mean period of $0^{d}.102$ and amplitude variations of $0^{m}.055$ and $0^{m}.025$ in the B filter. We put this star on our UBV photometric program for a detailed study of the light variation and the pulsation characteristics.

II. OBSERVATIONS

Photoelectric observations of 38 Cnc were taken on eight nights between March 1975 to January 1978, on the 38-cm Cassegrain reflector of the Uttar Pradesh State Observatory using a cooled 1P21 photomultiplier tube and UBV filters of the Johnson and Morgan system. The stars HD 73619 and HD 73598 were employed as comparison stars, of which the latter was found to be more stable than the former with a standard deviation of $\pm\ 0^{m}.007$ in the V filter. Hence the final reductions were done using HD 73598 only. The magnitudes

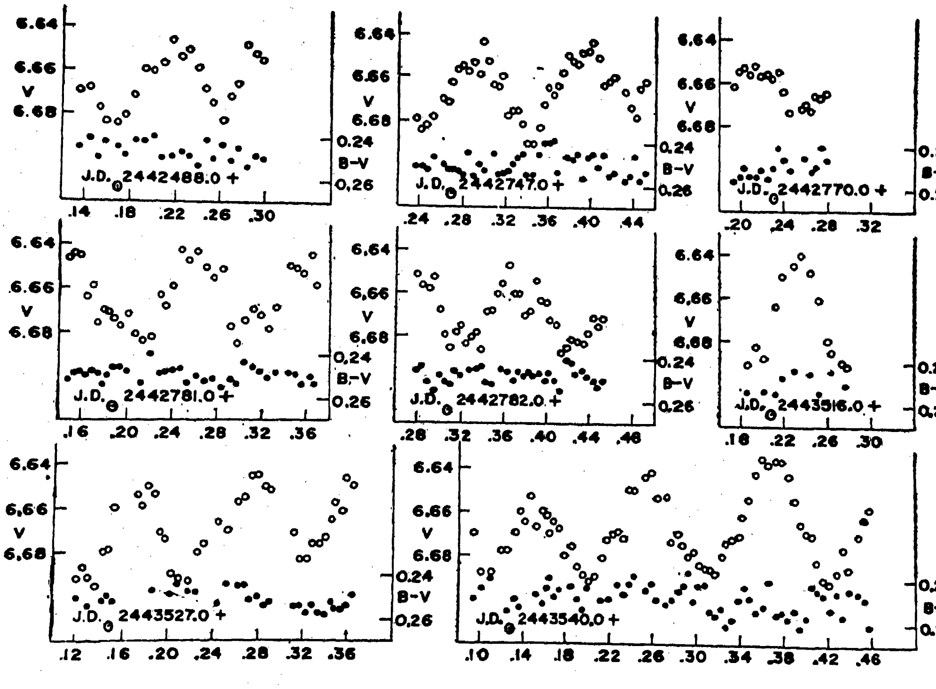

Fig. 1 : Light and colour curves of 38 Cnc.

Table 1

Magnitude and colours

JD (Hel) 2442000 +	V	B - V	U - B
	m	m	m
488.135	6.669	0.245	0.146
.144	6.668	.241	.139
.152	6.677	.250	.136
.159	6.683	.243	.151
.168	6.684	.245	.133
.175	6.680	.249	.138
.184	6.671	.242	.137
.192	6.659	.242	.148
.200	6.660	.240	.140
.209	6.656	.250	.154
.217	6.645	.249	.142
.225	6.653	.247	.148
.232	6.650	.250	.132
.240	6.658	.253	.147
.247	6.668	.241	.131
.254	6.674	.250	.136
.262	6.682	.244	.133
.269	6.671	.251	.141
.276	6.665	.245	.142
.248	6.646	.254	.140
.291	6.651	.249	.136
.297	6.654	.250	.142
747.237	6.679	.251	
.242	6.684	.251	
.246	6.682	.252	
.252	6.678	.247	
.262	6.670	.250	
.266	6.671	.252	
.270	6.662	.252	
.275	6.656	.253	
.280	6.654	.255	
.285	6.656	.245	
.290	6.653	.256	
.295	6.658	.250	
.299	6.643	.253	
.304	6.652	.269	
.309	6.663	.245	
.313	6.664	.255	
.317	6.659	.254	
.321	6.677	.253	
.326	6.675	.250	
.331	6.675	.247	
.335	6.681	.245	
.340	6.690	.255	
.345	6.690	.255	
.351	6.683	.245	
.356	6.672	.240	
.360	6.664	.246	
.365	6.667	.239	
.369	6.663	.254	
.374	6.657	.258	
.379	6.649	.246	
.383	6.652	.247	
.388	6.653	.245	
.393	6.648	.256	
.398	6.647	.246	
.402	6.643	.245	
.407	6.650	.251	
.412	6.663	.245	
.417	6.661	.255	
.422	6.659	0.254	

Table 1 (Contd.)

JD (Hel) 2442000+	V	B - V	U - B
	m	m	m
.432	6.666	0.258	
.437	6.673	.255	
.441	6.678	.246	
.446	6.664	.257	
.451	6.661	.254	
770.193	6.662	.256	
.198	6.655	.254	
.202	6.653	.250	
.207	6.656	.254	
.213	6.652	.254	
.218	6.657	.251	
.223	6.656	.255	
.228	6.658	.250	
.234	6.655	.240	
.239	6.664	.246	
.244	6.674	.251	
.255	6.672	.260	
.259	6.670	.245	
.264	6.673	.252	
.268	6.666	.250	
.273	.6667	.240	
.278	6.665	.246	
781.149	6.646	.252	
.154	6.644	.249	
.159	6.645	.248	
.164	6.664	.250	
.169	6.659	.248	
.174	6.676	.249	
.179	6.670	.254	
.183	6.671	.250	
.188	6.674	.246	
.193	6.677	.246	0.134
.200	6.672	.248	.139
.206	6.681	.258	.136
.213	6.684	.254	.134
.220	6.682	.240	.138
.229	6.663	.249	.155
.234	6.668	.248	.139
.240	6.659	.247	.140
.247	6.642	.247	.136
.254	6.647	.253	.151
.261	6.643	.250	.132
.269	6.650	.252	.141
.276	6.655	.251	.155
.284	6.651	.255	.132
.291	6.677	.251	.140
.297	6.685	.253	.147
.304	6.674	.242	.151
.311	6.669	.246	.153
.318	6.672	.248	.147
.325	6.678	.250	.134
.332	6.668	.248	.136
.343	6.649	.248	.132
.350	6.650	.249	.140
.356	6.652	.253	.136
.363	6.644	.250	.138
.366	6.658	.253	.144
782.280	6.651	.246	
.284	6.656	.244	
.290	6.658	.251	
.295	6.652	.255	

Table 1 (Contd.)

JD (Hel) 2442000+	V	B – V
782.300	6.667	0.248
.305	6.679	.251
.310	6.685	.252
.314	6.678	.246
.319	6.675	.248
.324	6.683	.258
.329	6.680	.245
.334	6.678	.245
.338	6.686	.244
.343	6.668	.251
.348	6.668	.252
.353	6.660	.256
.358	6.655	.245
.363	6.647	.246
.369	6.660	.250
.373	6.660	.246
.379	6.670	.248
.384	6.668	.246
.389	6.654	.248
.394	6.663	.247
.399	6.664	.250
.402	6.672	.247
.407	6.674	.250
.413	6.687	.255
.418	6.685	.240
.422	6.681	.242
.427	6.682	.247
.434	6.683	.246
.438	6.678	.248
.443	6.671	.250
.447	6.675	.253
782.451	6.671	.251
1516.186	6.691	.254
.194	6.683	.261
.201	6.688	.254
.211	6.664	.255
.219	6.650	.247
.229	6.645	.244
.236	6.640	.256
.244	6.648	.245
.252	6.661	.254
.260	6.680	.256
.264	6.685	.244
.274	6.690	.256
.277	6.694	.250
1527.120	6.692	.251
.125	6.687	.257
.130	6.692	.255
.136	6.694	.258
.142	6.680	.252
.147	6.679	.250
.152	6.660	.252
.172	6.654	.257
1527.176	6.659	.258
.181	6.650	.258
.187	6.654	.247
.192	6.671	.255
.197	6.674	.257
.202	6.690	.249
.208	6.692	.243
.218	6.693	.248
.226	6.680	.248
.232	6.676	.256
.244	6.666	.253

Table 1 (Contd.)

JD (Hel) 2442000+	V	B—V
.252	6.670	.244
.261	6.657	.245
.267	6.655	.245
.273	6.645	.251
.279	6.645	.250
.285	6.650	.254
.290	6.652	.252
.311	6.671	.254
.317	6.683	.254
.323	6.683	.257
.328	6.676	.254
.334	6.676	.257
.340	6.673	.258
.345	6.665	.252
.348	6.657	.255
.355	6.661	.255
.358	6.646	.254
1527.365	6.649	.249
1540.094	6.670	.250
.101	6.688	.245
.110	6.688	.240
.120	6.678	.263
.125	6.678	.255
.132	6.670	.250
.137	6.660	.254
.141	6.665	.256
.147	6.653	.258
.152	6.667	.248
.158	6.660	.252
.161	6.662	.245
.164	6.670	.240
.169	6.665	.249
.174	6.668	.246
.179	6.680	.256
.185	6.676	.244
.190	6.685	250
.195	6.689	.255
.200	6.692	.240
.206	6.690	.258
.213	6.681	.250
.218	6.673	.250
.223	6.670	.259
.228	6.669	.243
.233	6.672	.248
.238	6.650	.243
.243	6.650	.239
.253	6.644	.246
.258	6.642	.243
.264	6.654	.250
.272	6.653	.252
.277	6.674	.250
.283	6.670	.246
.287	6.675	.243
.292	6.680	.237
.297	6.678	.250
.302	6.684	.244
.307	6.689	.243
.312	6.686	.255
.317	6.687	.257
.322	6.680	.254
.327	6.674	.262
.333	6.672	.259
.338	6.671	.250
.342	6.662	.244

Table 1 (Contd.)

JD (Hel) 2442000+	V	B − V
	m	m
1540.348	6.654	0.249
.354	6.642	.255
.360	6.635	.253
.365	6.638	.241
.372	6.636	.256
.378	6.636	.255
.383	6.643	·258
.389	6.654	.254
.394	6.665	.262
·400	6.669	.257
.405	6.670	.243
.410	6.682	.245
416	6.690	.247
.421	6.694	.254
.428	6.687	.246
.434	6.676	.257
.439	6.685	.245
.448	6.670	.246
.453	6:663,	.249
.458	6.658	.261

were corrected for extinction using nightly extinction coefficients. The instrumental magnitudes and colour indices were transformed to the standard U, B, V system by using the transformation equations (Hardie 1962):

$$\Delta V = \Delta v_i + 0.059 \, \Delta(B-V),$$
$$\Delta(B-V) = 1.011 \, \Delta(b-v)_i,$$
$$\Delta(U-B) = 1.089 \, \Delta(u-b)_i,$$

where ΔV, $\Delta(B-V)$ and $\Delta(U-B)$ have been computed in the sense "variable minus comparison", from the instrumental differental magnitude and colour indices Δv_i, $\Delta(b-v)_i$ and $\Delta(u-b)_i$.

The final V, (B − V) and (U − B) magnitudes of the variable (listed in Table 1) were obtained by adding ΔV, $\Delta(B-V)$ and $\Delta(U-B)$ to V, (B − V) and (U − B) magnitudes of the comparison star. The light and colour curves are plotted in Fig. 1.

III. PERIOD

The complexity in the light variation of 38 Cnc suggests a beat phenomenon (Fig. 1). Following the method of Wehlau and Leung (1964), a periodogram analysis of V observations has ben carried out for a number of trial frequencies. The largest peak is obtained at 9.776 c/d (Fig. 2) which corresponds to a period of $0^d.10229$. This corresponds to and improves the value of $0^d.102$ obtained by Guerrero (1975). After subtracting the contribution due to this peak (i.e. after prewhitening the data) the periodogram analysis of the residuals showed the tallest peak (Fig. 3) to be at 7.865 c/d ($= 0^d.12715$). This development assumes that the spacing of the observations is at a constant interval (Kendall 1951). This assumption is approximately satisfied for our observations on any one night. As the spacing of our observations taken on different nights, is not at constant interval, the application of this procedure yielded peaks in the periodogram on each side of the peak at 9.776 c/d. These subsidiary peaks or aliases complicate

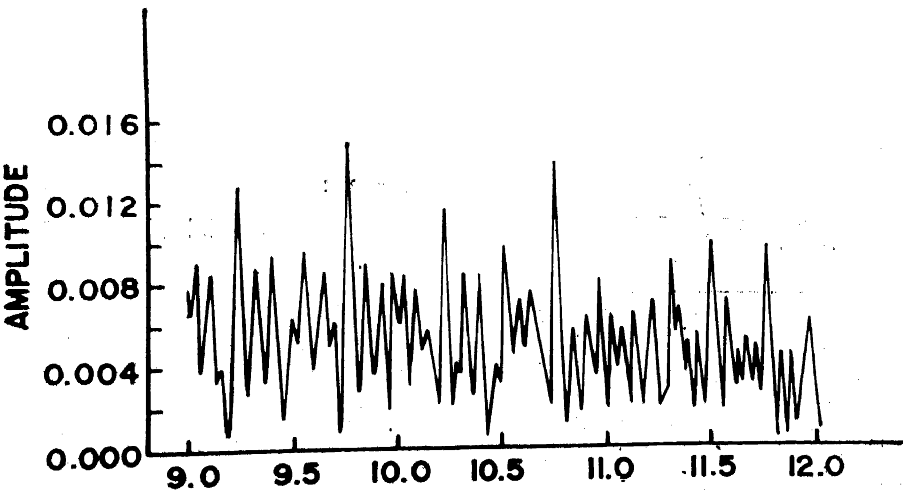

Fig. 2 : Periodogram analysis for 38 Cnc using observations in V.

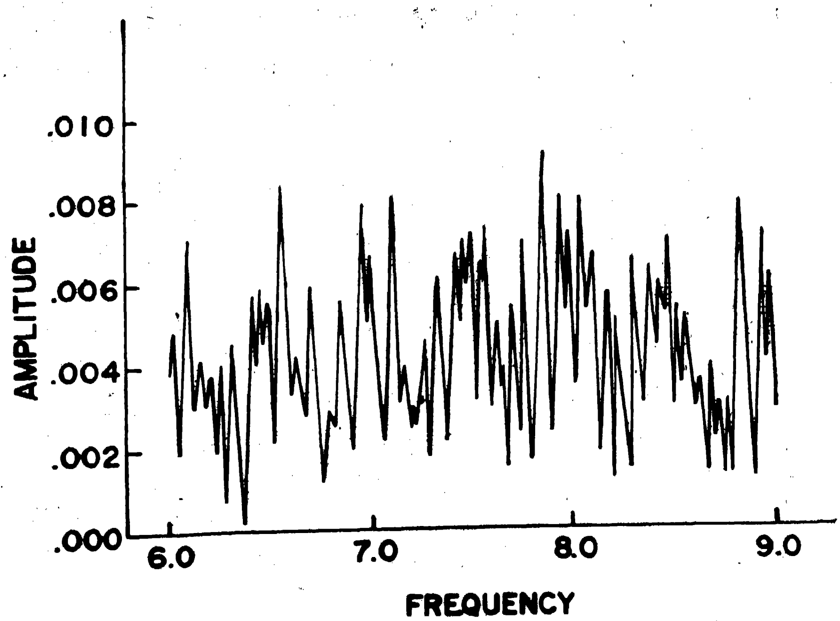

Fig. 3 : Periodogram analysis of the residuals for 38 Cnc after substraction of the peak at 9.776 c/d.

the spectrum and make the identification of the frequencies present in the light variation rather difficult. These effects can best be explained with the help of Fourier transform amplitude spectrum. However, we have carried out the least square solution to obtain the periods.

Starting from a preliminary period of $0^{d}.102$ and using our own V observations of 12 epochs of maxima (tabulated in Table 2), the (O − C) residuals were calculated for each observed time of maximum and after plotting Σ (O-C)^2 against various assumed values of the period, the value of the primary period, corresponding to minimum Σ (O-C)^2 was obtained to be $0^{d}.102209 \pm 0^{d}.000001$ (Fig. 4). This is in fair agreement with the period determined from the periodogram analysis. Likewise, based on the least square method for the prewhitened data, the secondary period was found to be $0^{d}.127100 \pm 0^{d}.000001$ (Fig.5). The two values of the secondary period, determined from two different methods, are again fairly consistent. The implications of the primary and secondary periods are discussed in the sequel.

Table 2

Epochs of Maxima JD (Hel)	O − C
2442488.215	$0^{d}.0000$
2747.292	−.0228
2747.393	−.0240
2781.257	+.0088
2781.357	+.0068
2782.371	−.0015
3516.236	+.0029
3527.175	+.0055
3527.277	+.0053
3540.144	−.0060
3540.252	−.0002
3540.366	+.0116

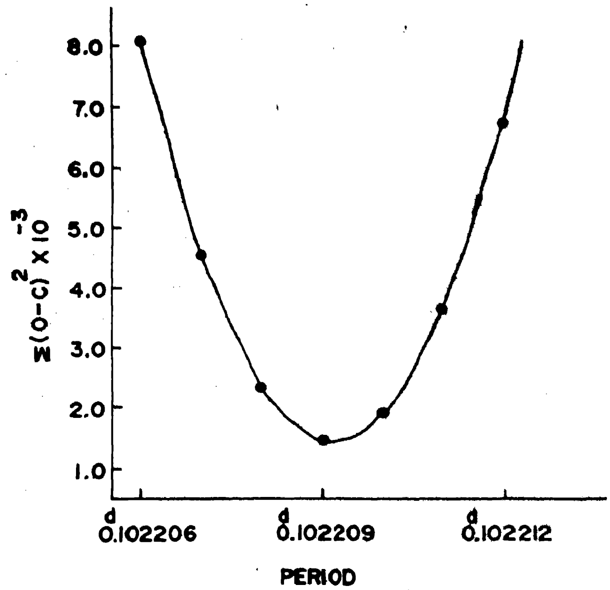

Fig. 4 : Plot between trial values of primary period versus Σ (O–C)^2 for 38 Cnc.

IV. DISCUSSION

No variation exceeding $\pm 0^{m}.01$ about a mean value is found in the (B–V) and (U–B) colours of 38 Cnc during its pulsation. The B and V light curves are thus in phase with the V light curve, making it unprofitable to carryout periodogram analysis of the former. The mean values of B–V and U–B are found to be $+0^{m}.25 \pm 0^{m}.01$ and $+0^{m}.14 \pm 0^{m}.01$ respectively which are in agreement with the values determined by Johnson (1952).

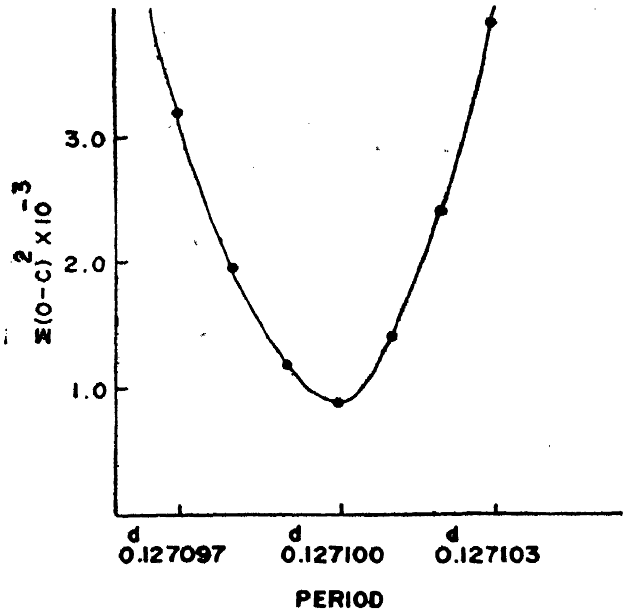

Fig. 5 : Plot between trial values of secondary period versus Σ (O–C) ^{2} for 38 Cnc.

Using the (B–V) – (b–y) calibration (Golay 1972) and the T_e – (b–y) calibration (Bregar 1975), the effective temperature of the star is derived to be 7800°K while from uvbyβ photometry Breger and Bregman (1975) had derived the effective temperature to be 7700°K. According to Breger (1974), the hot δ Scuti variables ($T_e \geqslant$ 7800°K) pulsate in overtones. It may therefore well be that the pulsation in 38 Cnc is in overtones.

Further, using the period $0^d.10229$ and the related parameters T_e, M_{bol} derived by us and using the value of gravity derived from uvbyβ photometry by Petersen and Jorgensen (1972), we have obtained the value of Q to be $0^d.019$ from the relation given by Breger and Bregman (1975). This value is closer to the value $0^d.0203$ derived from model calculations for δ Scuti stars pulsating in the second overtone. Similarly, from the period $0^d.12715$, the value of Q is derived to be $0^d.023$ which is closer to the value $0^d.0252$ from model calculations for first overtone δ Scuti pulsators (Petersen 1975). Thus, it appears that the star 38 Cnc pulsates in the second overtone with a period (P_2) of $0^d.10229$ as well as in the first overtone with a period (P_1) of $0^d.12715$. Further, from periodogram analysis, the amplitude of the light variation is larger for the second overtone than for the first overtone, indicating that the second overtone mode is more prominent in the pulsation of the star. The period ratio P_2 / P_1 is found to be 0.804 which is in good agreement with the theoretical value of 0.806 for radial mode δ Scuti pulsators (Petersen 1975). Thus, the hypothesis that the beat phehomenon in the δ Scuti variables is produced due to the superposition of two or more radial modes is supported.

From the cluster modulus of $6^m.15$ (Breger and Bregman 1975) and the mean visual magnitude of $6^m.67$ obtained by us in this investigation, the absolute V-magnitude is derived to be $0^m.52$. Applying the bolo metric correction of $-0^m.06$ (Allen 1973), the bolometric magnitude is derived to be $0^m.46$.

From the relation $Q = P\sqrt{\rho/\rho_\odot}$, the value of $\rho/\rho_\odot$ =0.038, where ρ is the density of the star. Based on Iben's (1967) evolutionary tracks for the stars in the hydrogen shell burning stage of evolution, the mass of the star is derived to be 2.2 $M_\odot$, while Petersen and Jorgensen (1972) derived its mass to be 2.32 $M_\odot$. From the values of mass and density obtained by us, the radius of the star is derived to be 2.4 $R_\odot$.

ACKNOWLEDGEMENT

The author wishes to express his thanks to Dr. S. D. Sinvhal for guidance and helpful discussions. Thanks are also due to Dr. M. C. Pande for constant encouragement during the course of this work.

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