A NEW CEPHEID VARIABLE, HD 200925

T. D. PADALIA and S. K. GUPTA
Uttar Pradesh State Observatory, Naini Tal, India

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Abstract. Photoelectric observations of the star HD 200925 in the standard *UBV* system have been secured and analysed. The period is determined to be $0^{d}.267\,394$. From the period and shape of the light and colour curves, the star HD 200925 appears to be a dwarf cepheid. The physical parameters have been derived. The mass derived for this star is found to agree well with the value inferred from the evolutionary tracks. The star appears to be a post-Main Sequence star in the hydrogen shell burning stage of evolution. The spectral class, for this star, is assigned to be F2 III.

1. Introduction

The star HD 200925 [$\alpha(1900) = 21^{h}1^{m}.4$, $\delta(1900) = +50°24'$] is discovered to be a variable by Bedolla and Pena (1979). They observed the star on four consecutive nights in *V* filter only. On the basis of these observations they reported a tentative period of $0^{d}.238$. Their four individual light curves revealed the variability of the star but left the question about the type of its variability open. The star could very well be an extrinsic (eclipsing variable) or an intrinsic (pulsating) variable. Therefore to investigate its nature of variability we put the star HD 200925 on our observing programme. The star was observed by us on seven nights in *UBV* filters and the light curves were analysed. The physical parameters e.g., effective temperature, mass, gravity etc. have therefore been derived by considering the star to be a pulsating variable.

2. Observations

Photoelectric observations of HD 200925 were taken on seven nights during October to December 1979 on 38-cm Cassegrain reflector of the Uttar Pradesh State Observatory using a cooled 1P21 photomultiplier tube and *UBV* filters of Johnson and Morgan system. The two stars HD 200926 and HD 200739 were taken as the comparison stars of which the star HD 200739 was found to be more stable than the star HD 200926 with a standard derivations of $\pm 0^{m}.015$, $\pm 0^{m}.010$ and $\pm 0^{m}.010$ in *U*, *B*, and *V* filters respectively. Hence all the reductions were done using the star HD 200739 only. The magnitudes were corrected for extinction using nightly extinction coefficients.

The instrumental magnitudes and colour indices were transformed to the standard *U*, *B*, *V* system by use of the following transformation equations

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(Hardie, 1962):

$$\Delta V = \Delta v_i - 0.059\Delta(B - V)\,,$$

$$\Delta(B - V) = 1.235\Delta(b - v)_i\,,$$

$$\Delta(U - B) = 1.024\Delta(u - b)_i\,,$$

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

The final V, $(B - V)$, and $(U - B)$ magnitudes of the variable can be obtained respectively by adding V, $(B - V)$, and $(U - B)$ magnitudes of the comparison star. The V, $B - V$, and $U - B$ of the comparison star are respectively $8^m.46$, $0^m.02$, and $0^m.06$. The photoelectric observations of the variable star are listed in Table I and are displayed against phase in Figure 1.

TABLE I(A)
Standard U magnitudes of HD 200925

JD (Hel)	Phase	ΔU Var.-Comp.	JD (Hel)	Phase	ΔU Var.-Comp.
2444					
162.1363	0.9402	$-0^m.230$	165.2818	0.7043	$0^m.123$
1535	0.0048	−0.324	2876	0.7300	0.075
1704	0.0681	−0.304	2954	0.7550	0.063
164.1209	0.3625	0.183	3007	0.7752	0.061
1425	0.4433	0.249	172.1204	0.2788	0.057
1611	0.5128	0.231	1293	0.3121	0.163
1802	0.5843	0.209	1350	0.3334	0.155
2026	0.6680	0.163	1430	0.3633	0.175
2199	0.7327	0.095	1495	0.3876	0.204
2352	0.7899	0.038	1556	0.4105	0.218
2432	0.8199	−0.041	1615	0.4325	0.204
2588	0.8792	−0.084	1685	0.4587	0.223
2651	0.9018	−0.141	1752	0.4838	0.215
2794	0.9552	−0.222	1819	0.5088	0.205
2859	0.9795	−0.293	1880	0.5316	0.204
2986	0.0270	−0.297	1953	0.5589	0.183
3044	0.0487	−0.290	2087	0.6090	0.170
3224	0.1160	−0.165	2506	0.7657	0.024
165.2196	0.4710	0.227	2585	0.7953	0.005
2246	0.4903	0.234	2658	0.8226	−0.013
2313	0.5151	0.218	2711	0.8424	−0.072
2375	0.5380	0.228	2779	0.8678	−0.135
2436	0.5610	0.236	2835	0.8888	−0.180
2488	0.5812	0.213	2906	0.9153	−0.221
2547	0.6031	0.213	2953	0.9329	−0.274
2632	0.6342	0.188	3015	0.9561	−0.292
2698	0.6590	0.147	3006	0.9752	−0.286
2755	0.6801	0.121	3118	0.9946	−0.302

Table I(A) (continued)

JD (Hel)	Phase	ΔU Var.-Comp.	JD (Hel)	Phase	ΔU Var.-Comp.
2444.					
173.0944	0.9214	$-0^m.172$	178.2144	0.0690	$-0^m.297$
1037	0.9561	−0.253	2209	0.0933	−0.180
1125	0.9891	−0.279	2286	0.1221	−0.133
1209	0.0205	−0.285	2378	0.1565	−0.112
1287	0.0496	−0.267	2476	0.1932	−0.051
1368	0.0799	−0.205	2569	0.2280	0.042
1455	0.1125	−0.216	2655	0.2602	0.084
1542	0.1450	−0.151	2737	0.2907	0.102
1635	0.1798	−0.078	2797	0.3132	0.152
1719	0.2112	−0.014	2853	0.3342	0.196
1797	0.2404	0.050	212.0475	0.5972	0.198
1966	0.3036	0.127	0527	0.6167	0.163
2024	0.3253	0.161	0592	0.6410	0.165
2088	0.3492	0.194	0652	0.6634	0.127
2159	0.3757	0.196	0710	0.6851	0.131
2224	0.4001	0.191	0762	0.7046	0.060
2273	0.4184	0.213	0839	0.7334	−0.008
2314	0.4337	0.205	0919	0.7633	0.037
2403	0.4670	0.216	0995	0.7919	0.031
178.1075	0.6692	0.161	1059	0.8156	−0.103
1209	0.7193	0.086	1125	0.8403	−0.094
1285	0.7478	0.031	1183	0.8620	−0.174
1352	0.7728	0.013	1252	0.8878	−0.329
1448	0.8087	0.008	1314	0.9110	−0.192
1526	0.8379	−0.062	1377	0.9346	−0.260
1653	0.8854	−0.148	1436	0.9566	−0.283
1738	0.9172	−0.285	1506	0.9829	−0.364
1780	0.9329	−0.285	1575	0.0086	−0.386
1876	0.9688	−0.304	1640	0.0329	−0.363
1956	0.9987	−0.343	1704	0.0568	−0.340
2045	0.0354	−0.304	1772	0.0823	−0.265

TABLE I(B)
Standard B magnitudes of HD 200925

JD (Hel)	Phase	ΔB Var.-Comp.	JD (Hel)	Phase	ΔB Var.-Comp.
2444					
162.1373	0.9439	$-0^m.261$	164.2440	0.8228	$-0^m.082$
1560	0.0142	−0.328	2596	0.8812	−0.133
1716	0.0725	−0.258	2654	0.9029	−0.158
164.1219	0.3662	0.100	2805	0.9594	−0.277
1435	0.4470	0.149	2867	0.9825	−0.300
1620	0.5162	0.168	2994	0.0300	−0.324
1814	0.5887	0.128	3054	0.0525	−0.320
2036	0.6718	0.065	3231	0.1187	−0.261
2212	0.7376	0.013	165.2204	0.4741	0.154
2361	0.7933	−0.031	2254	0.4935	0.153

Table I(B) (continued)

JD (Hel)	Phase	ΔB Var.-Comp.	JD (Hel)	Phase	ΔB Var.-Comp.
2444					
165.2321	0.5192	$0^m.166$	173.2030	0.3275	$0^m.078$
2383	0.5413	0.158	2091	0.3503	0.085
2446	0.5651	0.152	2165	0.3780	0.128
2497	0.5840	0.130	2230	0.4023	0.132
2555	0.6070	0.130	2318	0.4352	0.135
2640	0.6372	0.056	2408	0.4689	0.130
2708	0.6625	0.046	178.1092	0.6756	0.067
2763	0.6842	0.034	1214	0.7212	−0.005
2828	0.7080	0.013	1292	0.7504	−0.020
2892	0.7351	0.021	1359	0.7754	−0.010
2964	0.7593	−0.013	1453	0.8106	−0.043
3016	0.7790	−0.020	1531	0.8398	−0.097
3051	0.7920	−0.015	1661	0.8884	−0.198
172.1212	0.2818	0.029	1744	0.9194	−0.269
1299	0.3143	0.040	1788	0.9359	−0.296
1356	0.3357	0.108	1882	0.9710	−0.310
1436	0.3656	0.118	1962	0.0010	−0.328
1501	0.3899	0.125	2053	0.0322	−0.287
1562	0.4127	0.145	2150	0.0713	−0.281
1621	0.4348	0.160	2217	0.0963	−0.261
1691	0.4609	0.149	2294	0.1251	−0.169
1758	0.4860	0.148	2384	0.1588	−0.129
1823	0.5103	0.145	2482	0.1954	−0.082
1887	0.5343	0.130	2575	0.2302	−0.053
1959	0.5612	0.116	2661	0.2624	0.021
2025	0.5859	0.107	2748	0.2949	0.063
2512	0.7691	−0.031	2803	0.3155	0.093
2591	0.7925	−0.068	2856	0.3353	0.106
2664	0.8248	−0.072	212.0483	0.6002	0.047
2717	0.8446	−0.076	0538	0.6208	0.050
2789	0.8708	−0.117	0601	0.6443	0.038
2841	0.8910	−0.140	0662	0.6672	0.007
2912	0.9176	−0.185	0718	0.6881	0.000
2959	0.9352	−0.233	0774	0.7090	−0.010
3020	0.9580	−0.243	0855	0.7393	−0.098
3071	0.9770	−0.289	0935	0.7693	−0.055
3124	0.9969	−0.297	1007	0.7962	−0.085
173.0954	0.9251	−0.237	1069	0.8194	−0.131
1043	0.9584	−0.267	1135	0.8441	−0.164
1130	0.9909	−0.289	1192	0.8654	−0.201
1215	0.0227	−0.287	1262	0.8915	−0.276
1293	0.0519	−0.268	1324	0.9147	−0.291
1375	0.0825	−0.229	1387	0.9383	−0.321
1462	0.1151	−0.211	1444	0.9596	−0.335
1546	0.1465	−0.171	1517	0.9869	−0.341
1641	0.1820	−0.106	1586	0.0127	−0.334
1724	0.2131	−0.053	1650	0.0367	−0.281
1803	0.2426	−0.029	1714	0.0606	−0.248
1903	0.2800	0.045	1758	0.0770	−0.214
1971	0.3054	0.060			

TABLE I(C)
Standard V magnitudes of HD 200925

JD (Hel)	Phase	ΔV Var.-Comp.	JD (Hel)	Phase	ΔV Var.-Comp.
2444					
162.1386	0.9491	$-0^m.450$	172.2918	0.9198	$-0^m.423$
1578	0.0210	−0.448	2966	0.9378	−0.445
1728	0.0770	−0.461	3024	0.9662	−0.480
164.1228	0.3696	−0.190	3078	0.9797	−0.472
1445	0.4507	−0.145	3132	0.9998	−0.493
1628	0.5192	−0.150	173.0961	0.9277	−0.402
1825	0.5929	−0.174	1049	0.9606	−0.430
2047	0.6759	−0.214	1137	0.9935	−0.463
2370	0.7967	−0.283	1221	0.0250	−0.457
2453	0.8277	−0.312	1299	0.0541	−0.436
2606	0.8849	−0.327	1383	0.0855	−0.412
2666	0.9074	−0.381	1470	0.1181	−0.391
2813	0.9623	−0.468	1552	0.1487	−0.356
2875	0.9855	−0.468	1648	0.1846	−0.336
3003	0.0334	−0.459	1732	0.2161	−0.293
3068	0.0577	−0.450	1811	0.2456	−0.272
3237	0.1209	−0.399	1915	0.2845	−0.233
165.2213	0.4781	−0.168	1977	0.3077	−0.206
2262	0.4960	−0.150	2034	0.3290	−0.197
2331	0.5222	−0.134	2097	0.3526	−0.185
2392	0.5451	−0.148	2171	0.3802	−0.173
2454	0.5680	−0.150	2237	0.4049	−0.150
2505	0.5870	−0.144	2286	0.4232	−0.162
2563	0.6092	−0.175	2325	0.4378	−0.156
2651	0.6421	−0.182	2422	0.4741	−0.148
2716	0.6660	−0.192	178.1096	0.6771	−0.208
2771	0.6882	−0.206	1219	0.7231	−0.229
2835	0.7100	−0.212	1298	0.7526	−0.263
2973	0.7621	−0.239	1364	0.7777	−0.287
3025	0.7812	−0.219	1457	0.8121	−0.325
172.1219	0.2844	−0.211	1544	0.8446	−0.358
1303	0.3158	−0.206	1668	0.8910	−0.409
1362	0.3379	−0.188	1750	0.9217	−0.441
1441	0.3675	−0.172	1793	0.9377	−0.461
1509	0.3929	−0.159	1890	0.9740	−0.483
1568	0.4149	−0.163	1968	0.0032	−0.498
1629	0.4378	−0.134	2061	0.0380	−0.482
1698	0.4636	−0.167	2158	0.0743	−0.463
1764	0.4882	−0.150	2230	0.1012	−0.398
1833	0.5141	−0.167	2302	0.1281	−0.402
1895	0.5372	−0.166	2393	0.1621	−0.367
1969	0.5649	−0.163	2491	0.1988	−0.335
2035	0.5896	−0.178	2583	0.2332	−0.269
2107	0.6165	−0.201	2670	0.2657	−0.249
2521	0.7713	−0.269	2750	0.2956	−0.220
2671	0.8274	−0.333	2809	0.3177	−0.191
2724	0.8473	−0.329	2860	0.3368	−0.173
2797	0.8746	−0.362	212.0491	0.6032	−0.215
2849	0.8940	−0.376	0546	0.6238	−0.217

Table I(C) (continued)

JD (Hel)	Phase	ΔV Var.-Comp.	JD (Hel)	Phase	ΔV Var.-Comp.
2444					
212.0608	0.6470	$-0^m.211$	212.1272	0.8953	$-0^m.428$
0669	0.6698	−0.242	1330	0.9170	−0.460
0725	0.6907	−0.248	1395	0.9413	−0.469
0783	0.7124	−0.241	1454	0.9634	−0.503
0865	0.7431	−0.286	1527	0.9907	−0.509
0945	0.7730	−0.285	1597	0.0168	−0.457
1016	0.7995	−0.307	1661	0.0408	−0.424
1077	0.8224	−0.368	1726	0.0651	−0.413
1145	0.8478	−0.413	1747	0.0729	−0.386
1201	0.8687	−0.365			

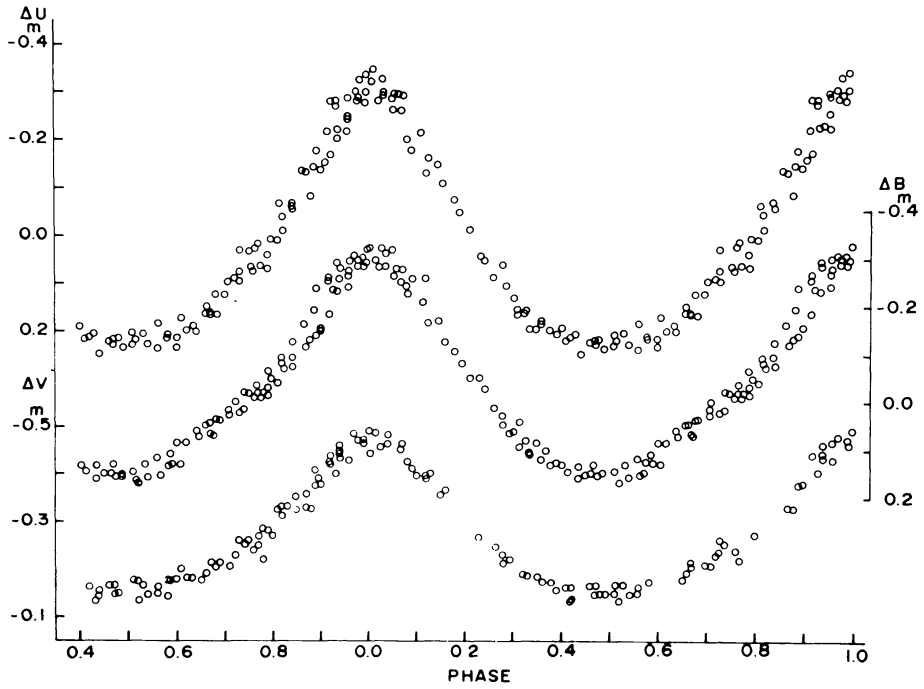

Fig. 1. Observed light curves of HD 200925 in *U*, *B*, *V*.

3. Analysis of Light Curves and Period

The star was first treated by us as an eclipsing variable. Therefore, time of the minimum (JD 2 443 776.715) of one of the individual light curves by Bedolla and Pena was considered as the epoch of the primary minimum and the above period of $0^d.238$ was adopted to construct a light curve over the entire phase region using all their *V* observations as well as our *UBV* observations taken nearly after one year from those taken by Bedolla and Pena. The light curve thus

obtained did not have a shape corresponding to the light curve of an eclipsing binary. Further the individual light curves were not found to be consistent when compared against each other. The fractional and multiple of the above period ($0^d.238$) have also been tried out but no useful light curve could be obtained. The same process is repeated by considering the above epoch for any possible secondary minimum, but again a comprehensive light curve could not be constructed. Thus the period of $0^d.238$, as reported by Bedolla and Pena (1979), does not fit our observations taken after a span of one year in the sense of yielding a comprehensive light curve. Hence a search for a refined period was undertaken.

Combining three maxima of Bedolla and Pena with four maxima of present authors, we determined a period of $0^d.267\ 394$ by least-squares method. The times of maxima of all the observations with observed minus computed (O–C) values are given in the following table:

Times of Maxima	O–C
JD (Hel) 2 443 776.835	$0^d.000$
3 778.713	0.006
3 779.776	0.000
4 164.295	0.006
4 173.118	0.006
4 178.193	0.000
4 212.151	−0.001

With this new period and the above epoch, a comprehensive light curve was constructed. The shape of the light curve, thus obtained ruled out the possibility of its being Algol or β-Lyrae type eclipsing variable. However, there may be a remote possibility of its being a W UMa-type variable.

The star was then considered a pulsating δ Scuti variable or a cepheid (Gupta and Padalia, 1980). The epoch was taken as the first maximum (JD_{Max} = 2 443 776.835) observed by Bedolla and Pena. With this new epoch and period ($0^d.267\ 394$), the *UBV* light and normal colour curves were constructed from our observations and are shown in Figure 1 and Figure 2, respectively. The phases for our individual observations, given in Table I, have been calculated with the aid of the ephemeris

$$JD_{Max}(\text{Hel}) = 2\,443\,776.835 + 0^d.267\,394\,E$$
$$\pm 0.002 \qquad \pm 2$$

and the normal colours determined at various phases covering the whole cycle are listed in Table II.

The shapes of the light and colour curves indicate that the star under study appears to be a pulsating variable rather than W UMa-type eclipsing variable.

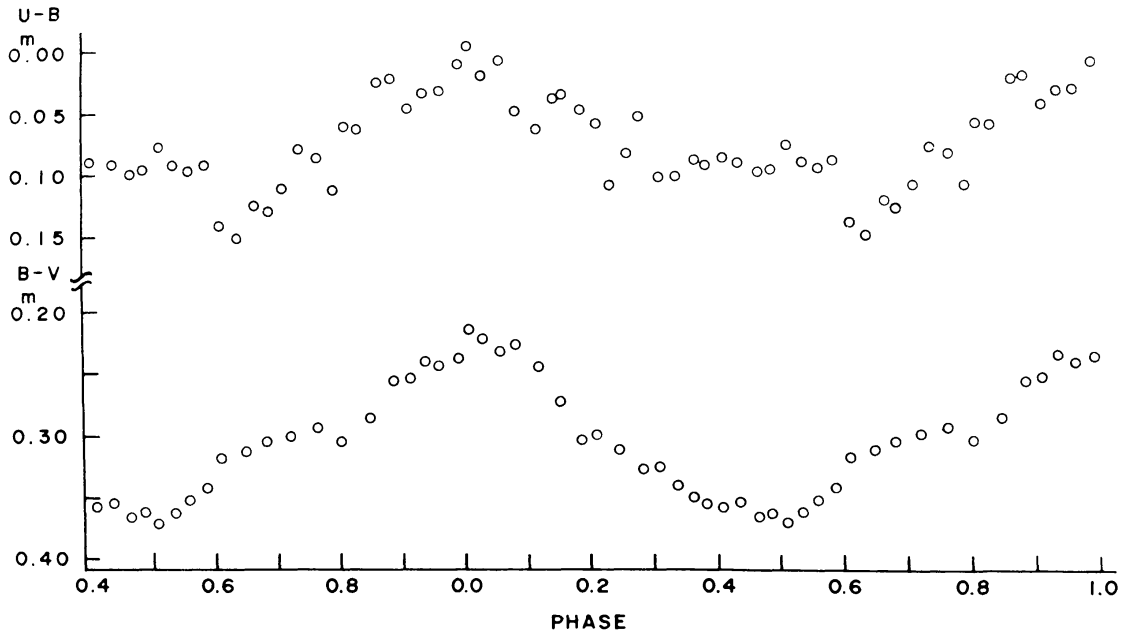

Fig. 2. Colour curves of HD 200925.

TABLE II

Normal colours of HD 200925

Phase	$B-V$	$U-B$	Phase	$B-V$	$U-B$
0.438	$0^m.353$	$0^m.091$	0.913	$0^m.253$	$0^m.046$
0.466	0.365	0.098	0.937	0.239	0.035
0.487	0.361	0.094	0.964	0.243	0.033
0.512	0.370	0.077	0.991	0.237	0.012
0.535	0.361	0.092	0.009	0.214	−0.004
0.560	0.351	0.096	0.029	0.212	0.020
0.586	0.341	0.091	0.058	0.231	0.009
0.609	0.318	0.141	0.082	0.216	0.050
0.637	—	0.150	0.117	0.243	0.063
0.651	0.312	0.123	0.136	0.262	—
0.682	0.304	0.129	0.151	0.272	0.039
0.709	—	0.110	0.186	0.302	0.049
0.723	0.299	0.079	0.211	0.300	0.059
0.766	0.294	0.085	0.234	—	0.107
0.791	—	0.102	0.247	0.310	0.083
0.801	0.304	—	0.282	0.327	0.054
0.812	—	0.060	0.310	0.325	0.103
0.833	—	0.062	0.335	0.340	0.102
0.849	0.286	—	0.365	0.350	0.090
0.865	—	0.025	0.382	0.353	0.093
0.885	0.258	0.023	0.410	0.357	0.088

4. Discussion and Conclusions

The *UBV* light curves (Figure 1) of the star under study appear to be asymmetrical in shape with a comparative steep rising branch followed by a slow descending branch. The $B - V$ colour varies in phase with the V magnitude – i.e., bluer at the maximum than at minimum. The $(U - B)$ colour also varies during pulsation. The mean values of $(B - V)$ and $(U - B)$ colours are found to be $0^m.30$ and $0^m.07$, respectively. In the $(B - V)$ colour curve, a hump appears in the ascending branch at phase interval 0.5 to 0.8 while in $(U - B)$ colour curve, a hump in the descending branch appears near the phase interval 0.3 to 0.6. No appreciable change in the amplitude of light variation is found in the light curve of individual nights. This indicates that the period of the variable star is stable. The variations in the amplitude of light curves in U, B, and V magnitudes during a pulsation cycle are found to be $0^m.50$, $0^m.45$, and $0^m.32$, respectively. The mean V magnitude of the star is derived to be $8^m.4$. The $(B - V)$ colour variation during a complete cycle is found to be $0^m.14$. Thus, the short period, light and colour variation and the shape of the light curve place the star in the dwarf cepheid group.

The pulsation constant (Q) is derived to be $0^d.033$ which indicates that the star pulsates in the fundamental mode. The effective temperature (T_e) is derived to be 7100 K from the P–L–C relation given by McNamara and Feltz (1978). According to Breger (1979), the dwarf cepheids are the Population I normal δ Scuti stars with larger amplitudes and are in the immediate post-Main-Sequence phase of evolution evolving towards the giant branch with a mass near $2\,M_\odot$. For the sake of comparison, we have derived an effective temperature of 7000 K from Tsvetkov's P–L–C relation, based on linear non-adiabatic model calculations for δ Scuti stars pulsating in the fundamental mode. Both values of T_e, derived from two different P–L–C relations, are close to each other.

By use of the period-luminosity relation for dwarf cepheids, given by McNamara and Feltz (1978), the absolute magnitude (M_v) is derived to be $0^m.41 \pm 0^m.23$ while from period-colour luminosity relation given by Gupta (1978) for δ Scuti-stars pulsating in the fundamental mode, the absolute magnitude is derived to be $0^m.37 \pm 0^m.16$. Both values are close to each other. The period-luminosity relation is free from colour. Hence, it appears that the reddening is negligible in this star. On the basis of the colour indices $B - V = 0^m.30$ and $U - B = 0^m.07$, the spectral class of the star is assigned to be F2 III.

In the colour-magnitude diagram, we find that it lies within the cepheid instability strip. From the relations given by McNamara and Feltz (1978) for dwarf cepheids, the mean surface gravity ($\log g$), radius (R) and mass (M) of the star are derived to be 3.34, $4.9\,R_\odot$ and $1.8\,M_\odot$, respectively; while from empirical relation given by Breger (1979) for dwarf cepheids, the mass is derived to be $1.9\,M_\odot$. Based on Iben's (1967a, b) evolutionary tracks for Population I stars evolving from the Main Sequence towards the red giant branch, the mass of

the star is derived to be 2.0 $M_{\odot}$ which is close to the values derived from different relations applicable to dwarf cepheids.

Thus the short period, colour variations, shapes of the light and colour curves and the physical parameters derived by us place the star in the dwarf cepheid group of variables and the star is in the hydrogen shell burning stage of evolution.

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