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Dwarf cepheid AD CMi — revisited

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Abstract. An analysis of *UBVR* light variations of AD CMi is presented. The mean effective temperature derived from the intrinsic $(B - V)$ index is estimated to be 7400 K ± 100 K whereas that of the $(V - R)$ index value is 8425 K ± 120 K. The mean variation of temperature from the $(B - V)$ index over a pulsation cycle is almost twice that of the estimated $(V - R)$ index value. The estimated mass, radius and effective gravity values suggest that AD CMi is a normal population-I pulsating star and a member of the δ-Scuti group.

Key words : variable star—photometry—pulsation—dwarf cepheid

1. Introduction

The dwarf cepheid AD Canis Minoris (HD 64191) was discovered as a light variable by Hoffmeister (1934) and later confirmed by Zessewitch (1950), who classified it as an eclipsing binary system. Abhyankar (1959) through *UBV* photoelectric photometry reclassified the star as an ultra-short period variable with a period of 0.122972 day. New light curves were obtained by Anderson & McNamara (1961). Breger (1975) observed the star through *uvby* and H_β photometry and found it to be a member of large amplitude δ-Scuti group rather than a population II star. Balona & Stobie (1983) have reported *VRI* light curves and radial velocity curves. Jiang (1987) found that the pulsation period of the star is continuously increasing and suggested a quadratic ephemeris. Rodriguez *et al.* (1988) have obtained new *uvby* and H_β observations and also suggested a possibility of quadratic ephemeris from the analysis of the observed times of maximum light.

2. Observations

AD CMi was reobserved between 1985 and 1992 for eight nights through *UBVR* passbands of the Johnson (1964) system using the 48-inch reflector of the Japal-Rangapur Observatory. An uncooled EMI 6256 B photomultiplier was used and the output signal was recorded on a Honeywell-Brown strip-chart recorder through a DC-amplifier. BD + 1° 1939 (SAO 116097, HD 64561 A3) and BD + 1° 1944 (SAO 116106, HD 64632 F0) were used as a comparison and check stars respectively.

All observations were transformed onto the standard system through normal procedures. Table 1 gives the observational data where Δm gives the magnitude difference (variable – comparison) for a given passband. The adopted standard visual magnitude and the colour indices for the comparison star are :

Table 1. Observations

J.D. (Hel.) 2446392 +

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU
.3755	.539'	1.286	.3762	.545	1.291	.3771	.553	1.246
.3783	.563	1.276	.3789	.566	1.315	.3795	.572	1.282
.3802	.578	1.290	.3810	.584	1.315	.3816	.588	1.261
.3825	.596	1.292	.3833	.602	1.311	.3840	.607	1.271
.4023	.758	1.260	.4030	.764	1.269	.4037	.768	1.222
.4049	.777	1.195	.4067	.793	1.218	.4042	.773	1.213
.4081	.805	1.106	.4087	.807	1.201	.4074	.799	1.189
.4101	.820	1.080	.4107	.826	1.181	.4094	.814	1.155
.4124	.840	1.138	.4130	.844	1.139	.4115	.832	1.117
.4225	.922	1.060	.4232	.928	1.020	.4137	.850	1.072
.4248	.939	1.042	.4280	.967	.950	.4239	.934	.981
.4273	.961	1.070	.4302	.984	.944	.4262	.951	.952
.4296	.979	1.036	.4392	.057	.942	.4288	.973	.940
.4385	.051	1.019	.4414	.074	.946	.4308	.988	.916
.4407	.068	1.021	.4433	.090	.945	.4400	.064	.934
.4429	.088	1.015	.4459	.111	.976	.4420	.080	.953
.4451	.105	1.021	.4529	.168	1.007	.4444	.100	.967
.4523	.164	1.040	.4552	.188	1.006	.4468	.119	.977
.4546	.182	1.045	.4570	.201	1.009	.4536	.174	.996
.4565	.197	1.061	.4590	.219	1.011	.4559	.193	.993
.4583	.213	1.062	.4674	.287	1.054	.4577	.207	.999
.4664	.277	1.087	.4699	.307	1.072	.4596	.223	.997
.4690	.299	1.099	.4720	.324	1.096	.4682	.293	1.061
.4736	.336	1.140	.4741	.342	1.117	.4708	.314	1.069
						.4728	.330	1.085
						.4749	.348	1.053

J.D. (Hel.) 2447912 +

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU	FHJD	Phase	ΔR
.2639	.926	1.060	.2631	.918	.995	.2621	.910	.969	.2650	.934	1.009
.2686	.965	1.011	.2696	.973	.929	.2705	.977	.920	.2674	.953	1.004
.2730	.000	1.016	.2720	.992	.910	.2714	.984	.891	.2741	.008	0.974
.2903	.141	1.022	.2912	.148	.953	.2921	.152	.929	.2892	.129	0.889

(Continued)

Table 1. Continued

J.D. (Hel.) 2447912 +

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU	FHJD	Phase	ΔR
.2945	.172	1.060	.2937	.168	.966	.2928	.160	.948	.2953	.180	1.009
.2985	.207	1.067	.2994	.215	.993	.3003	.219	.988	.2978	.199	1.034
.3163	.352	1.170	.3154	.344	1.127	.3146	.336	1.070	.3171	.355	1.109
.3211	.391	1.187	.3221	.398	1.161	.3230	.406	1.158	.3201	.383	1.119
.3267	.434	1.211	.3259	.430	1.198	.3248	.418	1.140	.3274	.441	1.164
.3508	.633	1.281	.3519	.641	1.297	.3528	.648	1.277	.3498	.625	1.249
.3551	.668	1.307	.3542	.660	1.305	.3536	.652	1.246	.3559	.672	1.229
.3591	.699	1.297	.3601	.707	1.293	.3608	.711	1.232	.3583	.691	1.249
.3712	.797	1.216	.3720	.805	1.201	.3727	.809	1.187	.3703	.789	1.169
.3755	.832	1.196	.3744	.824	1.177	.3737	.816	1.138	.3764	.840	1.134
.3805	.871	1.135	.3815	.883	1.066	.3825	.891	1.005	.3794	.863	1.109
.3971	.008	1.004	.3960	.000	.927	.3947	.988	.899	.3985	.020	0.849
.4019	.047	1.004	.4028	.055	.910	.4038	.063	.895	.4010	.039	0.934
.4063	.082	1.003	.4054	.074	.921	.4046	.070	.907	.4073	.090	0.949
.4180	.180	1.059	.4172	.172	.967	.4159	.160	.990	.4188	.184	1.014
.4224	.215	1.062	.4235	.223	1.012	.4244	.230	1.024	.4214	.207	1.019
.4274	.254	1.106	.4263	.246	1.031	.4254	.238	1.028	.4284	.262	1.054

J.D. (Hel.) 2448001 +

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU
.1235	.512	1.265	.1245	.520	1.270	.1255	.527	1.209
.1281	.547	1.273	.1272	.539	1.296	.1266	.535	1.232
.1397	.641	1.280	.1388	.637	1.337	.1378	.629	1.366
.1438	.676	1.270	.1444	.680	1.306	.1454	.688	1.291
.1550	.766	1.259	.1559	.773	1.245	.1568	.781	1.279
.1591	.801	1.247	.1582	.793	1.219	.1577	.789	1.286
.1695	.883	1.131	.1686	.879	1.080	.1676	.871	.990
.1744	.926	1.064	.1753	.934	..982	.1763	.941	.966
.1854	.016	1.004	.1866	.023	.885	.1875	.031	.954
.1897	.051	1.030	.1888	.043	.930	.1882	.035	.901
.2060	.180	1.059	.2050	.172	.992	.2130	.238	.910
.2099	.215	1.083	.2113	.227	1.004			

J.D. (Hel.) 2448275.+

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU	FHJD	Phase	ΔR
.2868	.945	1.042	.2880	.953	.977	.2892	.965	.917	.2850	.930	1.049
.2924	.988	1.029	.2911	.980	.950	.2903	.973	.913	.2946	.008	0.979
.2961	.020	1.026	.2974	.031	.936	.2988	.043	.893	.2954	.016	0.984

(Continued)

Table 1. Continued

J.D. (Hel.) 2448275.+

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU	FHJD	Phase	ΔR
.3079	.117	1.011	.3099	.133	.956	.3143	.168	.946	.3065	.105	0.948
.3085	.121	1.018	.3163	.184	.994	.3156	.180	.974	.3185	.203	1.019
.3175	.195	1.054	.3270	.270	1.047	.3257	.262	1.013	.3293	.289	1.064
.3281	.281	1.101	.3325	.316	1.089	.3343	.332	1.081	.3304	.297	1.057
.3313	.305	1.102	.3375	.355	1.130	.3362	.348	1.102	.3418	.391	1.144
.3406	.383	1.134	.3387	.367	1.136	.3495	.453	1.195	.3534	.484	1.204
.3521	.477	1.226	.3509	.465	1.228	.3579	.523	1.251	.3548	.496	1.209
.3556	.504	1.255	.3568	.512	1.288	.3603	.543	1.265	.3645	.574	1.240
.3631	.566	1.279	.3620	.555	1.312	.3727	.645	1.279	.3757	.668	1.254
.3746	.656	1.309	.3736	.648	1.335	.3808	.707	1.262	.3774	.680	1.269
.3784	.688	1.290	.3797	.699	1.315	.3821	.719	1.281	.3852	.746	1.219
.3842	.734	1.286	.3831	.727	1.304	.3937	.813	1.152	.3968	.840	1.118
.3961	.832	1.182	.3950	.824	1.195	.4012	.875	1.050	.3981	.848	1.114
.3990	.855	1.152	.4002	.867	1.108	.4023	.883	1.030	.4048	.902	1.039
.4040	.898	1.108	.4030	.891	1.063	.4102	.949	.934	.4132	.973	0.989
.4122	.965	1.023	.4113	.957	.975	.4174	.008	.898	.4144	.980	0.969
.4155	.992	1.004	.4164	.996	.956						

J.D. (Hel.) 2448276.+

FHJD	Phase	ΔV	F. HJD	Phase	ΔB	FHJD	Phase	ΔU	FHJD	Phase	ΔR
.2375	.676	1.278	.2386	.684	1.303	.2399	.695	1.267	.2361	.664	1.239
.2432	.723	1.279	.2420	.711	1.292	.2413	.707	1.259	.2444	.730	1.214
.2467	.750	1.263	.2477	.758	1.259	.2488	.766	1.212	.2458	.742	1.219
.2565	.828	1.179	.2576	.840	1.162	.2586	.848	1.069	.2554	.820	1.144
.2616	.871	1.128	.2605	.863	1.109	.2597	.855	1.127	.2626	.879	1.069
.2652	.898	1.082	.2663	.910	1.027	.2674	.918	.994	.2636	.887	1.044
.2757	.984	1.009	.2772	.996	.942	.2784	.008	.915	.2745	.977	0.984
.2820	.035	1.004	.2807	.027	.920	.2798	.020	.894	.2831	.047	0.979
.2852	.063	1.016	.2863	.070	.923	.2875	.082	.901	.2844	.055	0.984
.3065	.234	1.076	.3077	.246	1.016	.3084	.250	1.039	.2957	.148	1.054
.3169	.320	1.155	.3179	.328	1.104	.3198	.344	1.136	.3038	.215	0.874
.3250	.387	1.161	.3239	.379	1.143	.3220	.363	1.156	.3052	.227	1.024
.3289	.418	1.159	.3301	.430	1.185	.3446	.563	1.245	.3157	.313	1.084
.3443	.543	1.253	.3458	.555	1.283	.3478	.570	1.260	.3261	.395	1.074
.3506	.594	1.264	.3495	.586	1.292	.3488	.578	1.246	.3275	.406	1.149
.3552	.633	1.267	.3563	.641	1.311	.3575	.652	1.274	.3428	.531	1.189
.3661	.719	1.286	.3672	.730	1.315	.3684	.738	1.282	.3515	.602	1.230
									.3542	.625	1.234
									.3649	.711	1.219

(Continued)

Table 1. Continued

J.D. (Hel.) 2448601.+

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU	FHJD	Phase	ΔR
.3053	.051	1.005	.3063	.59	.913	.3072	.066	.907	.3044	.043	0.954
.3092	.082	1.012	.3084	.078	.907	.3078	.074	.910	.3101	.090	0.959
.3118	.105	1.027	.3124	.109	.930	.3135	.117	.925	.3110	.098	0.961
.3157	.137	1.038	.3148	.129	.934	.3142	.125	.947	.3166	.145	0.974
.3236	.199	1.058	.3229	.195	.990	.3219	.188	.972	.3244	.207	0.989
.3259	.219	1.086	.3267	.227	1.047	.3275	.234	1.041	.3251	.215	0.974
.3297	.250	1.081	.3289	.242	1.004	.3284	.238	1.009	.3304	.258	0.974
.3319	.270	1.097	.3328	.277	1.018	.3335	.281	.985	.3312	.262	0.969
.3399	.332	1.151	.3407	.340	1.107	.3415	.348	1.082	.3391	.328	1.024
.3437	.363	1.142	.3429	.359	1.123	.3422	.352	1.090	.3443	.371	1.014
.3458	.383	1.150	.3466	.387	1.147	.3474	.395	1.124	.3451	.375	1.034
.3495	.410	1.187	.3486	.402	1.163	.3480	.398	1.136	.3502	.418	1.069
.3596	.492	1.221	.3587	.488	1.250	.3578	.480	1.212	.3606	.500	1.119
.3617	.512	1.217	.3629	.520	1.267	.3636	.527	1.220	.3614	.508	1.114
.3660	.547	1.251	.3653	.539	1.272	.3647	.535	1.247	.3670	.555	1.164
.3683	.563	1.279	.3689	.570	1.304	.3705	.582	1.277	.3678	.559	1.169
.3796	.656	1.283	.3697	.574	1.290	.3812	.668	1.273	.3790	.652	1.184
.3833	.688	1.292	.3803	.660	1.299	.3821	.676	1.258	.3842	.695	1.224
.3856	.707	1.306	.3826	.680	1.282	.3873	.719	1.256	.3850	.699	1.239
.3894	.734	1.291	.3864	.711	1.277	.3881	.727	1.250	.3903	.742	1.234
.3982	.809	1.237	.3886	.730	1.290	.3966	.793	1.191	.3988	.813	1.194
.4001	.824	1.182	.3974	.801	1.223	.4016	.836	1.108	.3996	.820	1.174
.4047	.859	1.156	.4008	.828	1.143	.4029	.848	1.073	.4054	.867	1.114
.4066	.875	1.107	.4037	.852	1.129	.4081	.887	1.044	.4062	.871	1.074
.4141	.938	1.067	.4073	.883	1.084	.4159	.953	.946	.4132	.930	1.019
.4179	.969	1.021	.4151	.945	0.994	.4166	.957	.905	.4187	.973	0.979
.4205	.988	0.988	.4173	.961	0.914	.4223	.004	.876	.4197	.980	0.959
.4251	.027	0.995	.4213	.996	0.887	.4231	.012	.879	.4260	.035	0.919
.4330	.090	1.053	.4237	.016	0.874	.4312	.074	.904	.4337	.098	0.954
.4349	.105	1.048	.4321	.082	0.907	.4365	.117	.904	.4345	.102	0.949
.4389	.137	1.009	.4357	.113	0.927	.4373	.125	.896	.4397	.145	0.974
.4412	.156	1.076	.4379	.129	0.895				.4406	.152	0.969

J.D. (Hel.) 2448707.+

FHJD	Phase	ΔV	FHJD	Phasc	ΔB	FHJD	Phase	ΔR
.1864	.055	0.982	.1875	.063	0.932	.1855	.047	0.954
.1897	.078	.986	.1908	.090	0.939	.1888	.074	0.969
.1931	.109	1.007	.1941	.117	0.947	.1919	.098	0.970

(Continued)

Table 1. Continued

J.D. (Hel.) 2448707.+

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔR
.2018	.180	1.038	.2029	.188	1.016	.2007	.168	1.019
.2063	.215	1.045	.2074	.223	1.036	.2054	.207	1.004
.2095	.242	1.074	.2107	.250	1.038	.2086	.234	0.984
.2179	.309	1.091	.2190	.316	1.102	.2168	.301	1.044
.2212	.336	1.109	.2224	.348	1.121	.2201	.328	1.084
.2247	.363	1.136	.2259	.375	1.138	.2235	.355	1.059
.2347	.445	1.198	.2360	.457	1.212	.2334	.434	1.164
.2385	.477	1.218	.2396	.484	1.238	.2373	.469	1.154
.2421	.508	1.213	.2434	.516	1.260	.2408	.496	1.194
.2505	.574	1.275	.2517	.586	1.332	.2495	.566	1.224
.2541	.605	1.267	.2552	.613	1.296	.2528	.594	1.239
.2576	.633	1.289	.2589	.645	1.315	.2564	.621	1.199
.2657	.699	1.276	.2696	.730	1.275	.2646	.688	1.239
.2693	.727	1.246	.2705	.738	1.281	.2682	.719	1.254
.2730	.758	1.230	.2742	.766	1.252	.2716	.746	1.214
.2811	.824	1.166	.2820	.832	1.103	.2799	.813	1.164
.2848	.852	1.098	.2858	.863	1.035	.2832	.840	1.094

J.D. (Hel.) 2448708.+

FHJD	Phase	ΔV	FHJD	Phase	ΔB	FHJD	Phase	ΔU	FHJD	Phase	ΔR
.1456	.852	1.106	.1468	.863	1.116	.1480	.871	1.031	.1437	.836	1.123
.1518	.902	1.062	.1529	.914	.998	.1539	.922	.896	.1506	.895	1.028
.1616	.984	1.001	.1628	.992	.927	.1638	.000	.858	.1605	.973	1.010
.1662	.020	0.981	.1673	.031	.929	.1683	.039	.869	.1652	.012	0.976
.1741	.086	1.000	.1750	.094	.942	.1764	.102	.900	.1731	.078	0.965
.1787	.121	1.022	.1796	.129	.971	.1804	.137	.957	.1778	.113	1.041
.1884	.199	1.091	.1895	.211	1.043	.1906	.219	.970	.1874	.191	1.000
.1929	.238	1.073	.1940	.246	1.058	.1950	.254	1.054	.1919	.230	1.002
.2022	.313	1.099	.2038	.328	1.094	.2046	.332	1.040	.2013	.305	1.045
.2067	.352	1.125	.2076	.355	1.094	—	—	—	.2059	.344	1.082
.2191	.449	1.201	.2198	.457	1.217	.2206	.465	1.212	.2171	.434	1.120
.2223	.477	1.229	.2231	.484	1.267	.2238	.488	1.224	.2216	.473	1.251
.2319	.555	1.269	.2330	.563	1.271	.2340	.570	1.242	.2308	.547	1.272
.2359	.586	1.281	.2371	.598	1.313	.2381	.605	1.319	.2350	.578	1.192
.2454	.664	1.298	.2465	.672	1.345	.2475	.684	1.305	.2444	.656	1.220
.2494	.695	1.306	.2504	.707	1.332	.2517	.715	1.290	.2483	.688	1.241
.2595	.777	1.243	.2606	.789	1.189	.2615	.797	1.149	.2583	.770	1.168
.2633	.809	1.176	.2641	.816	1.169	.2648	.824	1.121	—	—	—

$V = 8.20 \pm 0.02$, $(B - V) = 0.32 \pm 0.01$, $(U - B) = 0.13 \pm 0.02$,

$(V - R) = 0.12 \pm 0.01$, and for the check star, $V = 8.32 \pm 0.02$,

$(B - V) = 0.28 \pm 0.01$, $(U - B) = 0.15 \pm 0.02$ and $(V - R) = 0.42 \pm 0.03$.

The V-magnitude and the colour indices, $(B - V)$ and $(U - B)$ values obtained by us for the check star agree with Abhyankar's (1959) values within observational errors whereas the latter's photometry does not cover the R-passband photometry.

The phase of the light variation shown in the table was computed using the ephemeris given by Breger (1975).

$$\text{H.J.D. (Max)} = 2442429.4582 + 0^{d}.12297443\ E. \qquad \ldots (1)$$

Figure 1 (a-h) show the observed light variations of AD CMi against the computed phases in the observed passbands.

Table 2 gives the mean values for ΔV, ΔB, ΔU, ΔR and also $\Delta(B - V)$, $\Delta(U - B)$, and $\Delta(V - R)$ for equal interval of phase obtained from the smooth curves drawn through the observed points. Figure 2 shows the mean light variation over a single pulsation cycle in different passbands.

Though Jiang (1987) and Rodriguez *et al.* (1988) have shown from their observations that the period of AD CMi is continually increasing and the change in period (ΔP) between Breger (1975) and Rodriguez *et al.* (1988) is of the order of 12×10^{-8} days which roughly corresponds to $0^{s}.01$ in a pulsation cycle. As the accuracy of our observations is not of that order, we have used the period given by Breger without any correction in computing the phases. Though the non-application of the negligible period change might lead to a minute shift in the phase of the observed maximum of the star, this in no significant way affects the physical parameters derived here, and hence we have adopted only Breger's ephemeris in the present investigation.

3. Discussion

(a) *Colour excess*

The mean observed $(B - V)$ colour index of AD CMi at the time of maximum and minimum are $0^{m}.24$ and $0^{m}.36$ respectively. Abhyankar (1959) classified the star as F0 III and F3 III at maximum and minimum of light variation respectively. Using the intrinsic colour given by Fitzgerald (1970) for a given spectral type and luminosity class, one obtains a negative colour excess $E(B - V)$ at both maximum and minimum for the above observed spectral type and luminosity class.

McNamara (1965) gave a relation

$$(B - V)_0 = 0.23 \log P + 0.473 \qquad \ldots (2)$$

for short period, large amplitude variables and a value of $(B - V)_0 = 0.264$ has been obtained for the adopted period of AD CMi. The mean $(B - V)$ index over the pulsation cycle is estimated to be $0^{m}.30$ and thus, a colour excess, $E(B - V)$ of $0^{m}.04$ is obtained.

As a further check, the interstellar reddening arising from the galactic disk can be estimated from the Parenago formula, (Parenago 1945), a cosecant extinction relation, without recourse to the observations of AD CMi itself. The relation is

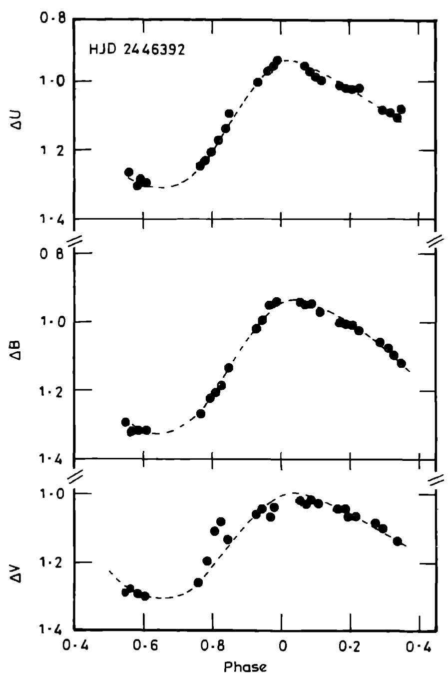

Figure 1a

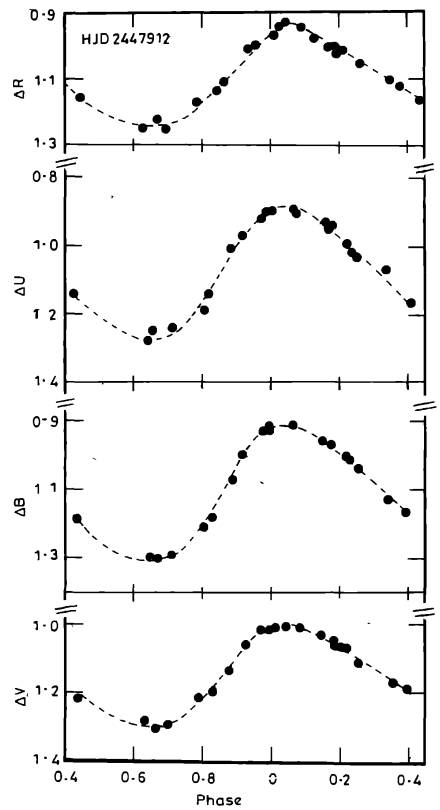

Figure 1b

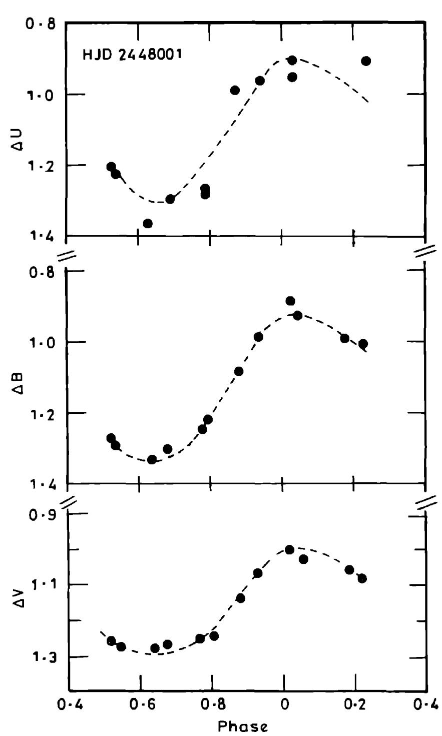

Figure 1c

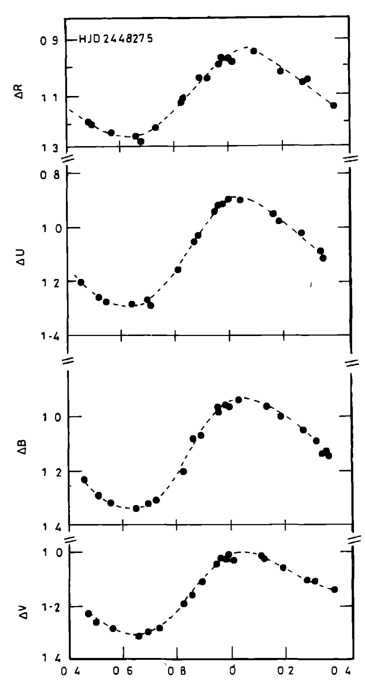

Figure 1d

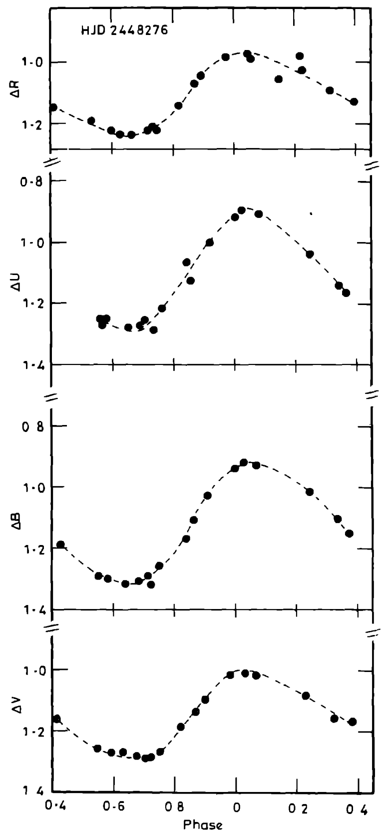

Figure 1e

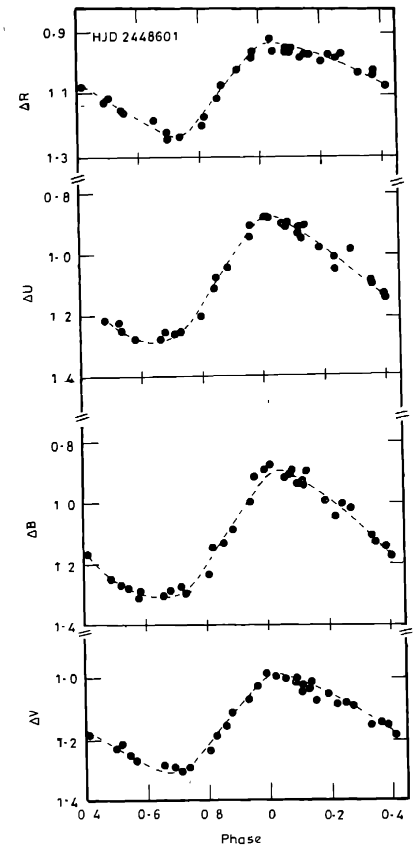

Figure 1f

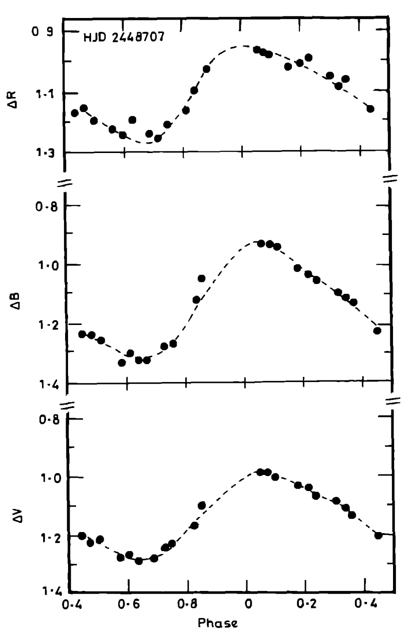

Figure 1g

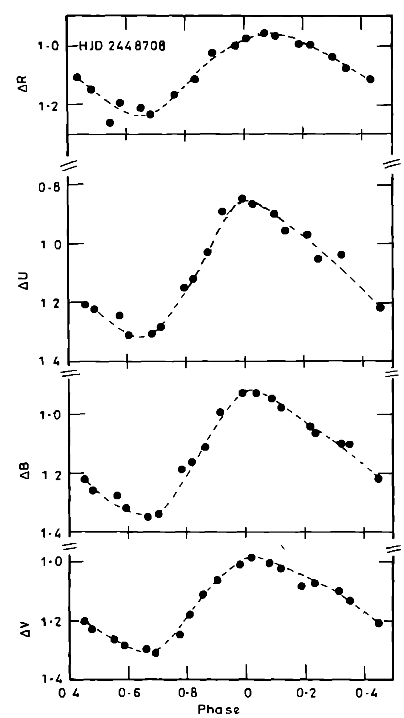

Figure 1h

Figure 1 (a to h). Observed light variations of AD CMi through UBVR pass bands on different heliocentric Julian Dates (in the sense AD CMi – BD + 1° 1939 against phase).

Table 2. Mean Δ magnitudes of AD CMi

Pass band Stan. Dev.	Phase 0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45
V	1.003(8)*	0.995(8)	1.014(8)	1.034(8)	1.059(8)	1.091(8)	1.114(7)	1.141(7)	1.176(8)	1.200(6)
	(0.006)	(0.008)	(0.007)	(0.007)	(0.008)	(0.012)	(0.015)	(0.014)	(0.010)	(0.006)
B	0.938(8)	0.928(8)	0.942(8)	0.969(8)	1.004(8)	1.041(8)	1.079(7)	1.125(7)	1.173(5)	1.214(5)
	(0.009)	(0.009)	(0.010)	(0.014)	(0.015)	(0.015)	(0.009)	(0.006)	(0.009)	(0.007)
U	0.895(7)	0.891(7)	0.913(7)	0.947(7)	0.986(7)	1.026(7)	1.065(6)	1.110(6)	1.150(3)	1.195(3)
	(0.018)	(0.014)	(0.011)	(0.010)	(0.008)	(0.007)	(0.014)	(0.016)	(0.010)	(0.018)
R	0.965(6)	0.949(6)	0.962(6)	0.979(6)	1.006(6)	1.033(6)	1.062(6)	1.092(6)	1.121(6)	1.149(6)
	(0.015)	(0.014)	(0.012)	(0.009)	(0.017)	(0.021)	(0.025)	(0.028)	(0.028)	(0.030)

Pass band Stan. Dev.	Phase 0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
V	1.234(8)	1.264(8)	1 289(8)	1.297(8)	1.288(8)	1.260(8)	1.211(8)	1.146(8)	1.089(8)	1.039(8)
	(0.010)	(0.013)	(0.008)	(0.010)	(0.009)	(0.015)	(0.019)	(0.021)	(0.015)	(0.007)
B	1.255(6)	1.295(8)	1.318(8)	1.324(8)	1.309(8)	1.276(8)	1.211(8)	1.129(8)	1.052(8)	0.979(8)
	(0.016)	(0.012)	(0.013)	(0.011)	(0.010)	(0.009)	(0.007)	(0.009)	(0.007)	(0.009)
U	1.229(4)	1.258(7)	1.285(7)	1.294(7)	1.280(7)	1.233(7)	1.161(7)	1.087(7)	1.013(7)	0.942(7)
	(0.014)	(0.016)	(0 013)	(0.009)	(0.012)	(0.010)	(0.011)	(0.013)	(0.014)	(0.021)
R	1.182(6)	1.212(6)	1.232(6)	1.244(6)	1.243(6)	1.217(6)	1.169(6)	1.112(6)	1.047(6)	1.005(6)
	(0.030)	(0.025)	(0.025)	(0.019)	(0.013)	(0.015)	(0.016)	(0.015)	(0.022)	(0.021)

* No. of data points from mean light curves.

$$A_v = \alpha_0 \beta \operatorname{cosec} |b| \, [1 - \exp \{(-r \sin |b|)/\beta\}] \qquad \dots (3)$$

where A_v is the visual absorption in magnitudes, α_0, the absorption in mag kpc^{-1} in a line parallel to the galactic plane, β the scale height, r the distance to the star in parsecs and b the galactic latitude of the star.

The parameters α_0, and β have been obtained by Sharov (1964), using distant OB stars, and $\alpha_0 = 1.4$ mag/kpc and $\beta = 96$ pc are appropriate for the position of AD CMi ($b^{II} = +15$). Obviously, the distance to AD CMi is not known and if we assume $M_v = +1.5$, which is appropriate and a mean value for the above mentioned spectral types at light maximum and minimum, a distance of 360 pc is estimated for the mean V magnitude and a value of $0^m.32$ for A_v. Assuming $R = 3.1$, one estimates the $E(B - V) = 0^m.10$ for AD CMi. The value of $E(B - V)$, thus derived, is somewhat higher than what we had obtained above and also from the values given by Abhyankar (1959) and Jones (1973), who had estimated the colour excess, $E(B - V) = 0^m.02$ and $0^m.00$ respectively from the broad-band photometry. Breger (1975) and Rodriguez *et al.* (1988) had estimated $E(b - y) = 0^m.015$ and $0^m.02$ respectively from the intermediate-band photometry. Hence, in the following discussion, we have adopted a value of $E(B-V) = 0.04$ and $E(U-B) = 0.03$.

Figure 3 gives the light and colour variation of AD CMi in V, $(B-V)$, $(U-B)$ and $(V-R)$, (in the sense variable – comparison). The observed amplitudes are $0^m.3$, $0^m.1$, $0^m.04$ and $0^m.03$ in V, $(B-V)$, $(U-B)$ and $(V-R)$, respectively. In the case of the V-passband and $(B-V)$ index, the maximum and minimum occurs around $\phi = 0.05$ to 0.10 and $\phi = 0.55$ to 0.65 respectively whereas in the case of the $(U-B)$ index a minimum occurs at $\phi = 0.25$ to 0.35 and gradually reaches a maximum level at $\phi = 0.8$ of the pulsation cycle. The $(V-R)$ index variation remain more or less constant with minimum fluctuations and reaches a peak between $\phi = 0.8$ to 0.95 of the pulsation cycle.

(b) *Temperature and spectral type*

Figure 4 shows the variations of $(B-V)_0$ and $(U-B)_0$ over the mean pulsation cycle. The loop structure is clearly visible, which is common for this kind of variable and suggests that temperature variations are more or less uniform except at maximum and minimum light. The mean observed position of AD CMi in this diagram suggest that it is somewhat metal deficient compared to the normal giants.

Using Fitzgerald (1970) calibration between $(B-V)_0$ and T_{eff}, the effective temperatures derived at maximum and minimum of the $(B-V)_0$ index are 7780 ± 80 K and 7040 ± 120 K with a mean of 7400 ± 100 K and a $\Delta T_{eff} = 740$ K and correspond to A7 III and F1 III respectively. In the case of the observed intrinsic $(V-R)$ index, from the calibrations given by Johnson (1966) and Mendoza (1968, 1969) between $(V-R)_0$ and T_{eff} the value of 0.12 at maximum corresponds to 8600 ± 100 K, while at minimum, $(V-R)_0 = 0.15$ corresponds

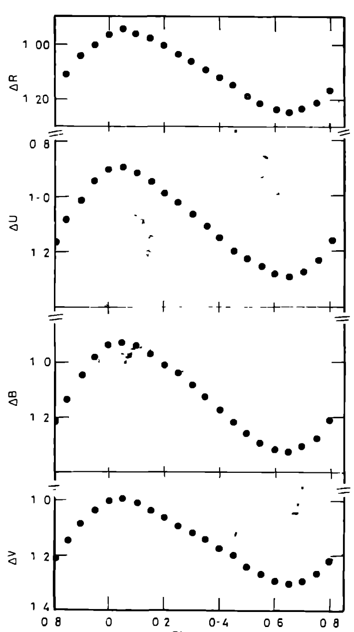

Figure 2. Mean light variations of AD CMi through UBVR passbands for all observations.

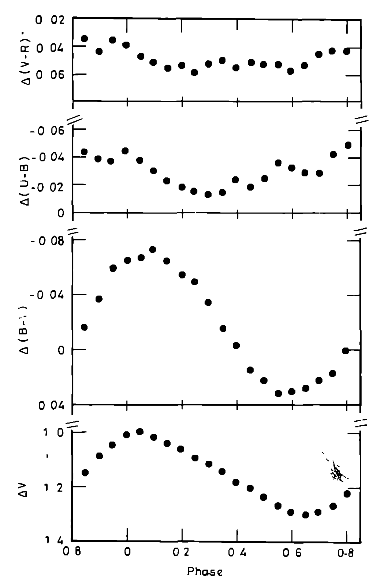

Figure 3. Mean light and colour variations of AD CMi (in the sense variable minus comparison) versus phase for all observed data.

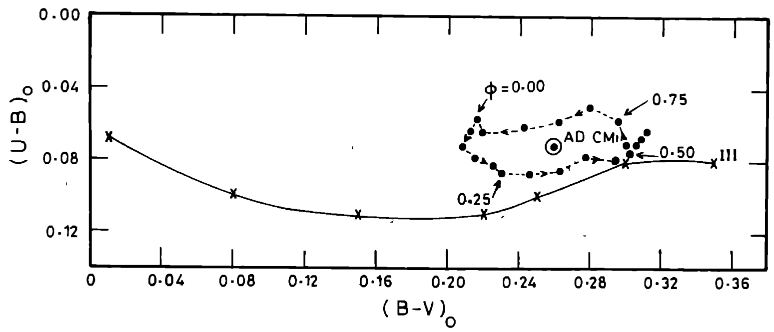

Figure 4. Intrinsic two-colour diagram. The loop is the observed path of variations of colour-indices through one mean cycle by AD CMi. The open circle with a dot in the middle represent the mean unreddened position of AD CMi. The dashed line represents the locus for luminosity class III stars.

to 8250 ± 140 K with a mean of 8425 ± 120 K and ΔT_{eff} = 350 K. These temperatures suggest that AD CMi has a spectral-type of A4-A5 III-V from this index. Thus, the analysis suggests that the range of effective temperature variation in $(B - V)$ is almost twice that of the variation observed in the $(V - R)$ index over a pulsation cycle. In addition, the spectral types derived here from intrinsic photometric indices are somewhat earlier than those given by Abhyankar (1959). The lesser range of temperature variation noticed over a pulsation cycle with the $(V - R)_0$ index and the higher temperatures estimated from the same index at maximum and minimum of the light variation when compared to that of $(B - V)_0$ index values needs further investigation. This could be due to (i) discrepancies between the effective temperature and $(V - R)_0$ index calibrations, (ii) over estimation of the interstellar reddening correction, and (iii) excess emission through R-passband.

The derived effective temperatures from the observed $(V - R)_0$ index have been obtained from the calibrations given by Johnson (1966) and Mendoza (1968, 1969) and the differences between these two calibrations are of minimal nature. The effective temperatures used for these calibrations were obtained from the measured angular diameters of the stars and also from the model atmospheres which predict the absolute spectral energy distribution as a function of effective temperature. In addition, a close look of the data used for obtaining the mean calibration curves indicate that the difference between the data and the mean do not deviate by more than ± 100 K around the $(V - R)_0$ index range under consideration. The question of the over estimation of the interstellar reddening correction does not seem to be possible at all as the estimated colour excess from the $(B - V)$ index in this analysis agrees with that of the narrow-band photometric investigations and also the temperatures derived from $(B - V)_0$ index and the distance obtained for AD CMi agrees closely with that of other investigators. Thus, the higher temperatures derived from $(V - R)_0$ index may be due to the excess emission recorded through R-passband. Balona & Martin (1978), while evaluating the radius of another dwarf cepheid, RS Gruis, through a modified Baade-Wesselink method, obtained a larger photospheric displacement than that of the reversing layer, thereby leading to a larger radius for the star over a complete pulsation cycle with $(V - R)$ and $(V - I)$ indices. The exclusion of the phase range covering the rising branch have yielded a smaller value for the radius, which almost agrees with that of $(B - V)$ index analysis obtained over a complete cycle. Thus the difference in the radius estimates has been attributed to the excess radiation through R and I passbands in the rising branch phase range. They suggest that the excess emission could be due to shock-wave radiation with a possible emission in

H_α which is situated almost in the middle of the R-passband. The effect of the H_α line emission in the V-magnitude results an abnormal $(V - R)$ index, bluer than it ought to be, thus leading to higher effective temperatures. They have expressed difficulty in understanding why the effect of this excess emission is so much less on the $(B - V)$ index. Balona & Stobie (1980) noticed a similar situation in the case of another dwarf cepheid, AI Vel. Thus, in the present analysis, we suggest that the behaviour of AD CMi emission in R-passband may be similar to the one discussed above. Unfortunately, no emission in H_α has been reported so far for any of these stars; a higher-dispersion study at H_α could settle this discrepancy. The remaining analysis is based only on the temperature estimated from $(B - V)_0$ index.

(c) *Absolute magnitude and gravity*

The absolute magnitude, M_v, for AD CMi is derived from the relation given by McNamara & Feltz (1978)

$$M_v = -3.25\ (\pm 0.12) \log P_f - 1.45\ (\pm 0.11) \qquad \ldots (4)$$

for short period and large amplitude stars and corresponds to a value of 1.51 ± 0.20 and a distance of 350 pc.

By allowing for a dependence on T_e as well as on P and using the other relation given by McNamara & Feltz

$$M_v = -4.10 \log P - 11.30 \log T_{eff} + 41.55 \qquad \ldots (5)$$

a value of $M_v = 1.56$ is obtained.

The estimated mean effective gravity of AD CMi, from the relation given by McNamra & Feltz (1978)

$$\log g = -1.16\ (\pm 0.10) \log P_f + 2.77\ (\pm 0.09) \qquad \ldots (6)$$

yields a mean value of $\log g_{eff} = 3.83 \pm 0.08$.

The radius of the star was estimated from the relation given by McNamara & Feltz (1978)

$$\log (R/R_\odot) = 0.80 \log P_f + 1.25 \qquad \ldots (7)$$

and has a value of $3.33\ R_\odot \pm 0.20$.

The equation for mass/luminosity ratio in solar units is given by McMillan *et al.* (1976)

$$\log m/L = \log g - 4 \log T_{eff} + 10.61 \qquad \ldots (8)$$

and corresponds to -1.04.

Figure 5 shows the position of AD CMi on $\log g - T_{eff}$ plane.

From the above equation (8) and the period-density relation $Q = P\sqrt{(\rho/\rho_\odot)}$ (McMillan *et al.* 1976)

$$\log Q - 0.1\ M_{bol} = -6.454 + \log P_f + 0.5 \log g + \log T_{eff} \qquad \ldots (9)$$

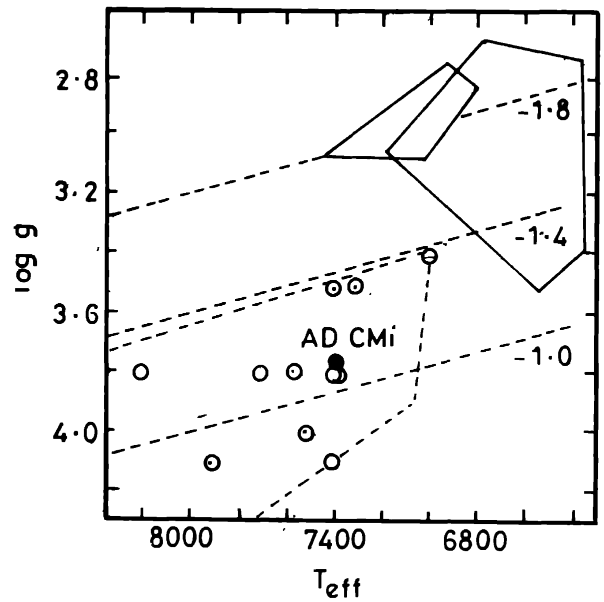

Figure 5. Log (surface gravity) versus effective temperature from McMillan *et al.* (1976). O = small amplitude variables, ⊖ = Known RRs stars; large Solid lined polygon : RRab stars; small solid lined polygon : RRc stars; dashed-line polygon : population 1 δ-Scuti stars. The three parallel lines corresponds to log $(m/L) = -1.0, -1.4$ and -1.8 as indicated.

where Q and P_f are in days. This yields a value of $(\log Q - 0.1\ M_{bol}) = -1.582$. This value agrees closely with that of the average value of -1.7 ± 0.1 given by Breger & Bergmann (1975) for δ-scuti stars with $T_{eff} \leq 7800$ K.

The absolute bolometric magnitude of AD CMi was computed from the relation given by Breger and Bregman (1975)

$$M_{bol}\ (\pm 0.26\ \text{mag}) = -2.84 \log\ P_f - 14.7 \log T_{eff} + 55.5 \qquad \text{... (10)}$$

and has a value of 1.207, thus leading to a value of $Q = 0.035$.

Finally, with the above derived parameters one could estimate the mass of AD CMi from the relation given by Danziger & Kuhi (1966),

$$\log m/m_\odot = (M_{bol\odot} - M_{bol})/2.5 + \log g/g_\odot - 4 \log T_e/T_{e\odot} \qquad \text{... (11)}$$

yields a mass of $2.37 \pm 0.25\ m_\odot$ for AD CMi, where we have used $M_{bol\odot} = 4.75$, $\log g_\odot = 4.44$ and $T_{eff\odot} = 5770$ K. Table 3 gives the mean physical parameters obtained in this analysis and also from other investigations.

4. Conclusion

The so-called dwarf cepheid AD CMi could be classified as a population I δ-Scuti object on the basis of the physical parameters obtained in this analysis. The nature of the stability of the period of pulsation and the estimated pulsation constant suggest that AD CMi is a radial pulsator. The effective temperature obtained from the $(B - V)$ index and the computed mean absolute visual magnitude indicates that AD CMi lies very close to the cool-edge of the instability strip of the population I stars in the colour-magnitude diagram. This conclusion

Table 3. Mean physical parameters of AD CMi.

	Present analysis	Rodriguez *et al.* (1988)	Breger (1975)
Photometry	*UBVR*	*uvby* Hβ	*uvby* Hβ
T_e	7400 ± 100 K	7550 ± 190 K	7580 ± 100 K
log *g*	3.83 ± 0.08	3.83 ± 0.06	3.90 ± 0.08
M_v	1.51 ± 0.20	1.68 ± 0.19	1.60 ± 0.30
$R/R_\odot$	3.33 ± 0.20	2.77 ± 0.21	3.00 ± 0.20
$m/m_\odot$	2.37 ± 0.25	1.90 ± 0.50	2.90 ± 0.60
d (pc)	350 ± 30	350 ± 50	—

agrees with that of Breger (1975) that the so-called dwarf-cepheids are also members of δ-Scuti group. The temperature variation obtained during a pulsation cycle from the $(B - V)_0$ index is almost twice that of $(V - R)_0$ index.

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