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Photometry of the Pulsating Variable HD 37819

by

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ABSTRACT

Comprehensive light curves of a newly discovered δ Scuti star HD 37819 in U, B and V filters have been presented and discussed. An improved period of $0^d.1892666$ has been obtained. The colours and physical parameters have been determined.

1. Introduction

HD 37819 (= BD +28°856) is a newly discovered variable star (Burki and Mayor, 1980). Radial velocity and photometric measurements were carried out by them on a total of 6 nights in March 1980. They observed the star spectroscopically and photometrically on the last two nights only. On the basis of these observations a period of $0^d.18916$ was determined by them. While our observations were in progress in 1981, Burki and Mayor (1981) analysed further their old observations in order to determine its mode of oscillations and physical parameters. However, they suggested that further observations only would give the possibility to determine which oscillation mode is predominant in the pulsation of HD 37819. Therefore photometric observations were continued by us to investigate nature of its variability, mode of pulsation and to determine its physical parameters. An improved period has been obtained since the period given by Burki and Mayor was based on observations taken by them at a span of 12 days only.

2. Observations

The star was observed photoelectrically on the 38-cm reflector of Uttar Pradesh State Observatory, using a cooled 1P21 photomultiplier tube and UBV filters of Johnson and Morgan system. A total of 10 nights

of observations have been obtained during the period January 1981 — December 1982. The two stars HD 37683 and HD 37557 were taken as the comparison stars of which the former was found to be more stable than the latter. Hence all the reductions were done using HD 37683 as the comparison star. The average standard deviations of the comparison star are $\pm 0^{m}.013$, $\pm 0^{m}.008$ and $\pm 0^{m}.006$ in U, B and V filters, respectively.

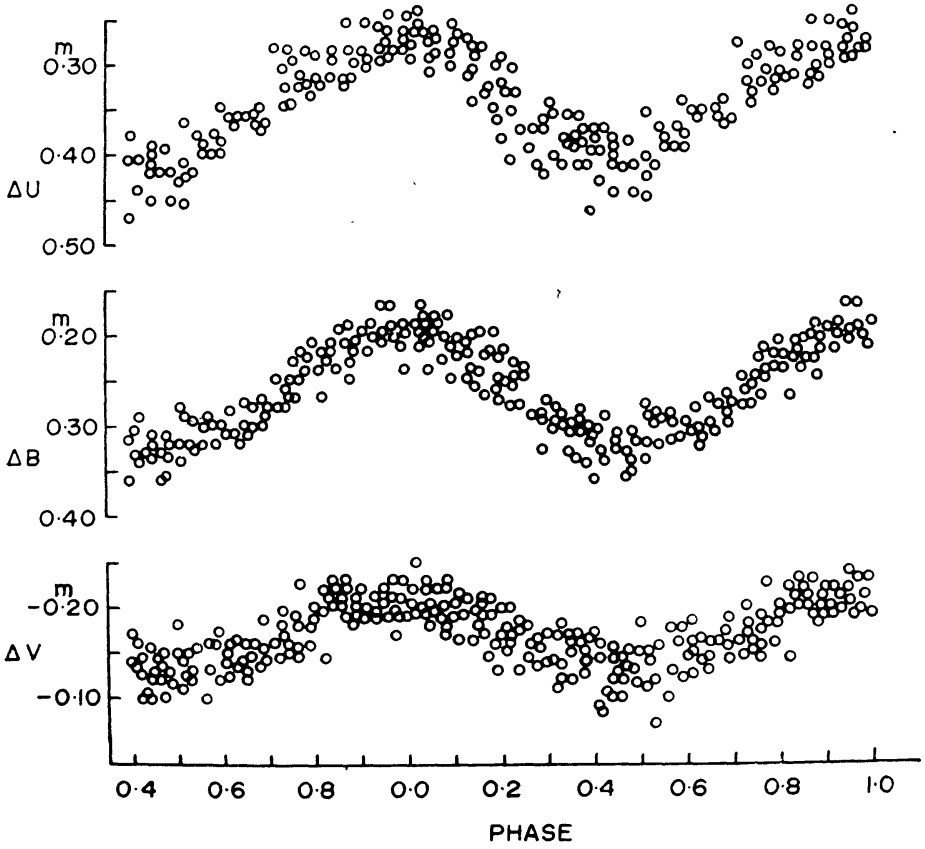

Fig. 1. Observed light curves of HD 37819 in U, B, V filters.

The instrumental magnitudes and colour indices were transformed to the standard UBV system. The differential magnitudes ΔU, ΔB, ΔV and $\Delta(U-B)$, $\Delta(B-V)$ are in the sense "variable *minus* comparison". The final U, B, V and $(U-B)$, $(B-V)$ magnitudes of the variable can be obtained respectively by adding corresponding magnitudes of the comparison star. The V, $B-V$ and $U-B$ values of the comparison star are respectively $8^{m}.01$, $0^{m}.11$ and $0^{m}.07$. The photoelectric observations of the variable star are listed in Table 1 and are displayed against phase in Figure 1.

Table 1a

Standard U magnitudes of HD 37819

JD(Hel)	Phase	ΔU	JD(Hel)	Phase	ΔU
2444			915.246	0.0627	$0^m.302$
618.102	0.9132	$0^m.293$	.250	.0838	.274
.108	.8794	.289	.263	.1525	.289
.115	.8429	.319	.269	.1842	.337
.122	.8086	.295	.272	.2000	.311
.129	.7726	.330	.276	.2212	.340
.135	.7383	.348	.280	.2423	.337
.142	.7013	.368	.289	.2899	.384
.157	.6252	.369	.295	.3216	.365
.164	.5840	.399	.299	.3427	.395
.171	.5481	.383	.305	.3744	.420
.177	.5159	.366	.314	.4220	.406
.184	.4820	.397	.319	.4484	.392
.190	.4482	.408	.326	.4854	.419
.197	.4128	.387	.331	.5118	.434
.203	.3785	.377	.336	.5382	.422
620.065	.5442	.425	.341	.5646	.389
.070	.5157	.456	.346	.5910	.379
.077	.4771	.418	926.136	.6006	.353
.089	.4169	.437	.140	.6217	.359
.094	.3862	.417	.149	.6692	.362
.100	.3572	.399	.153	.6904	.352
.106	.3260	.391	.158	.7168	.285
.111	.2964	.380	.162	.7379	.309
.123	.2330	.416	.166	.7591	.302
.129	.2050	.329	.171	.7855	.288
.135	.1728	.287	.184	.8542	.287
.141	.1379	.282	.189	.8806	.260
.147	.1062	.285	.197	.9229	.259
.154	.0703	.273	.202	.9493	.290
.161	.0333	.248	.206	.9704	.300
.168	.0026	.270	.210	.9915	.291
.183	.0824	.300	.250	.2029	.367
.189	.0999	.292	.263	.2716	.404
.196	.1490	.350	.268	.2980	.434
.202	.1807	.335	.278	.3508	.395
643.125	.2945	.383	.282	.3720	.388
.130	.3209	.412	2445		
.138	.3643	.404	319.121	.9553	.298
.145	.4028	.407	.133	.0198	.297
.153	.4462	.412	.140	.0594	.315
.168	.5233	.408	.148	.1012	.293
.175	.5608	.402	.157	.1450	.298
.182	.5973	.399	.169	.2089	.392
.189	.6358	.360	.180	.2691	.377
.198	.6813	.369	.192	.3304	.354
.211	.7537	.347	.195	.3457	.366
.223	.8155	.326	.199	.3690	.351
.252	.9671	.275	.201	.3822	.368
.258	.9983	.279	.207	.4139	.377
.264	.0337	.269	.215	.4535	.452
.271	.0691	.282	.218	.4704	.421
.277	.1081	.296	.229	.5286	.425
.284	.1372	.319	.234	.5566	.394
644.176	.8481	.297	.243	.5994	.386
.183	.8861	.307	.252	.6485	.361
.190	.9226	.297	.256	.6707	.369
.197	.9611	.277	.259	.6855	.376
.204	.9981	.288	.271	.7484	.342
.210	.0314	.273	.277	.7811	.316
.218	.0705	.296	.280	.7991	.326
.240	.1857	.356	.283	.8133	.317
.248	.2285	.358	.296	.8836	.321
.255	.2670	.380	.298	.8905	.359
.262	.3040	.374	.312	.9676	.270
.269	.3389	.387	.321	.0162	.277
.296	.3791	.395	.325	.0365	.265
.183	.4160	.406	.329	.0585	.279
.289	.4493	.398	.338	.1055	.258
915.185	.7404	.331	.342	.1235	.276
.189	.7983	.338	.347	.1488	.280
.224	.9464	.265	.353	.1832	.304
.228	.9676	.252	.358	.2075	.300
.236	.0098	.256	.362	.2232	.308
915.241	0.0363	0.268	319.372	0.2857	0.344

Table 1b

Standard B magnitudes of HD 37819

JD(Hel)	Phase	ΔB	JD(Hel)	Phase	ΔB
2444			915.189	0.7983	$0^m.277$
618.103	0.9084	$0^m.199$	.195	.7932	.237
.109	.8746	.206	.199	.8143	.237
.116	.8382	.220	.204	.8408	.223
.123	.8017	.213	.208	.8619	.208
.130	.7674	.222	.224	.9464	.171
.136	.7330	.265	.228	.9676	.174
.143	.6960	.287	.242	.0415	.169
.151	.6543	.275	.246	.0627	.187
.158	.6178	.285	.251	.0891	.184
.166	.5750	.298	.259	.1314	.213
.172	.5428	.295	.264	.1578	.201
.178	.5196	.283	.269	.1842	.224
.184	.4783	.309	.273	.2053	.218
.191	.4435	.320	.277	.2265	.251
.198	.4075	.299	.281	.2476	.242
.204	.3737	.295	.290	.2952	.276
620.060	.5690	.321	.296	.3269	.294
.065	.5395	.326	.300	.3480	.311
.071	.5099	.341	.306	.3797	.317
.078	.4723	.362	.310	.4008	.315
.083	.4454	.334	.315	.4272	.332
.089	.4126	.335	.320	.4537	.323
.095	.3815	.317	.327	.4906	.318
.101	.3524	.304	.332	.5171	.323
.107	.3207	.300	.337	.5435	.325
.112	.2911	.292	.342	.5699	.298
.118	.2605	.293	.346	.5910	.316
.124	.2282	.260	925.150	.3910	.343
.130	.2002	.253	.155	.4174	.331
.136	.1670	.225	.159	.4385	.332
.142	.1326	.220	.162	.4544	.323
.149	.1004	.216	.166	.4755	.355
.155	.0655	.194	.169	.4914	.316
.162	.0280	.198	.173	.5125	.322
.169	.0090	.192	.177	.5336	.301
.178	.0555	.204	.187	.5865	.324
.184	.0882	.214	.191	.6076	.313
.190	.1046	.211	.196	.6340	.325
.197	.1543	.237	.200	.6552	.311
.203	.1870	.274	.206	.6869	.298
643.124	.2892	.304	.209	.7027	.280
.131	.3278	.307	.214	.7291	.279
.139	.3701	.312	.218	.7503	.271
.146	.4081	.307	.222	.7714	.250
.154	.4520	.321	.226	.7925	.245
.169	.5286	.318	.230	.8137	.215
.176	.5671	.318	.234	.8348	.231
.183	.6025	.319	.240	.8665	.208
.190	.6411	.323	.251	.9246	.202
.199	.6876	.274	.256	.9510	.203
.206	.7230	.280	.261	.9775	.206
.213	.7616	.269	.266	.0039	.198
.224	.8208	.268	.270	.0250	.208
.232	.6404	.231	.275	.0514	.237
.239	.9000	.198	.280	.0778	.227
.252	.9687	.206	.285	.1043	.249
.259	.0036	.237	.291	.1360	.242
.266	.0395	.194	.297	.1677	.268
.272	.0738	.200	.302	.1941	.267
.278	.1071	.230	.307	.2205	.280
.285	.1420	.246	.312	.2469	.301
644.177	.8539	.240	926.136	.6006	.297
.184	.8919	.221	.141	.6270	.313
.191	.9273	.207	.145	.6481	.302
.199	.9690	.196	.150	.6745	.277
.205	.0023	.199	.158	.7168	.254
.211	.0372	.207	.162	.7379	.261
.219	.0763	.207	.167	.7643	.233
.226	.1133	.225	.171	.7855	.226
.233	.1524	.257	.176	.8119	.226
.242	.1962	.276	.181	.8383	.214
.248	.2327	.283	.185	.8595	.197
.256	.2718	.294	.189	.8806	.188
.263	.3080	.305	.194	.9070	.197
.270	.3489	.302	.198	.9281	.192
.277	.3838	.345	.202	.9493	.205
.284	.4208	.340	.206	.9704	.203
.290	.4536	.336	.211	.9968	.190
915.185	0.7404	0.277	926.251	0.2082	0.279

Table 1b — concluded

JD(Hel)	Phase	ΔB	JD(Hel)	Phase	ΔB
926.255	0.2293	0.m279	319.201	0.3790	0.m299
.264	.2769	.303	.208	.4165	.288
.274	.3297	.311	.214	.4472	.324
.278	.3508	.328	.217	.4667	.330
928.159	.2852	.299	.230	.5307	.290
.169	.3420	.298	.235	.5603	.304
.179	.3949	.317	.243	.6020	.310
.189	.4477	.310	.252	.6506	.299
.203	.5217	.294	.257	.6749	.298
.213	.5745	.288	.260	.6897	.290
.223	.6273	.306	.271	.7510	.251
.237	.7013	.295	.277	.7837	.237
.284	.9496	.210	.279	.7933	.239
.292	.9919	.211	.284	.8165	.223
.300	.0342	.216	.296	.8799	.229
.310	.0870	.218	.298	.8926	.245
.319	.1346	.252	.313	.9724	.140
2445			.322	.0194	.188
319.120	.9506	.203	.326	.0416	.179
.132	.0161	.209	.330	.0622	.184
.141	.0621	.216	.337	.0992	.177
.149	.1049	.226	.341	.1193	.206
.158	.1503	.239	.345	.1393	.195
.169	.2121	.256	.354	.1890	.199
.181	.2734	.253	.357	.2017	.225
.191	.3257	.278	.361	.2233	.232
.196	.3526	.293	319.371	0.2778	0.254
319.199	0.3716	0.286			

3. Analysis of light curves and period

Burki and Mayor (1981) have not mentioned epoch of maximum adopted by them. Moreover their 3 night's photometric observations when plotted are not sufficient to define maxima accurately. Therefore, time of the maximum (JD 2444620.1675) of one of the individual light curves obtained by us was considered as the epoch of maximum and the period of $0^d.18916$ given by Burki and Mayor (1981) was adopted to construct a light curve over the entire phase region. The comprehensive light curve for our 10 nights of observations was drawn, but with this period no useful light curve could be obtained. Hence search for a refined period was undertaken.

Combining nine maxima taken by us during an interval of about 2 years, a period of $0^d.1892666 \pm 0.0000005$ has been determined by least-squares method and is shown in Figure 2. From this period a satisfactory light curve could be drawn. The observed *minus* computed $(O-C)$ values of the maxima obtained from the period given by Burki and Mayor and with our period are given in Table 2.

It is evident from this table that the period of $0^d.1892666$ determined by us is more reliable. With this epoch (JD 244620.1675) and period of $0^d.1892666$, *UBV* light curves are constructed from our observations and are shown in Figure 1. The phases for our individual observations given in Table 1 have been calculated with the aid of the ephemeris:

$$\mathrm{JD(Hel)} = 2444620.1675 + 0^d.1892666\ E \pm 5$$

Table 1c

Standard V magnitudes of HD 37819

JD(Hel)	Phase	ΔV	JD(Hel)	Phase	ΔV
2444			915.196	0.7985	$-0^m.200$
618.104	0.9037	$-0^m.223$	.200	.8196	.195
.110	.8693	.229	.205	.8460	.218
.117	.8323	.218	.209	.8672	.194
.124	.7980	.197	.213	.8883	.191
.131	.7626	.177	.218	.9147	.220
.137	.7283	.168	.225	.9517	.217
.144	.6913	.186	.229	.9729	.228
.152	.6490	.158	.233	.9949	.234
.159	.6125	.148	.238	.0204	.253
.167	.5708	.163	.242	.0415	.227
.173	.5386	.154	.247	.0680	.219
.179	.5048	.178	.252	.0944	.227
.186	.4720	.135	.259	.1314	.208
.192	.4387	.117	.264	.1578	.207
.199	.4033	.171	.269	.1842	.193
.205	.3690	.164	.274	.2106	.178
620.061	.5643	.097	.277	.2265	.171
.066	.5352	.155	.281	.2476	.186
.072	.5062	.142	.291	.3004	.144
.079	.4681	.148	.296	.3269	.178
.084	.4401	.156	.301	.3533	.150
.090	.4084	.094	.306	.3797	.154
.096	.3772	.125	.311	.4061	.160
.102	.3477	.159	.315	.4272	.147
.108	.3165	.110	.320	.4537	.133
.113	.2869	.165	.328	.4959	.150
.119	.2557	.181	.332	.5171	.149
.125	.2240	.161	.337	.5435	.152
.131	.1950	.156	.346	.5910	.175
.137	.1617	.208	925.155	.4174	.101
.143	.1279	.208	.159	.4385	.101
.149	.0956	.207	.163	.4597	.122
.156	.0608	.222	.166	.4755	.127
.163	.0232	.215	.169	.4914	.116
.172	.0254	.197	.173	.5125	.108
.179	.0597	.180	.177	.5336	.074
.185	.0935	.202	.188	.5918	.124
.191	.1094	.201	.191	.6076	.125
.198	.1590	.171	.196	.6340	.143
.204	.1918	.133	.201	.6604	.146
643.123	.2839	.139	.206	.6869	.156
.133	.3331	.135	.210	.7080	.162
.140	.3764	.140	.214	.7291	.177
.147	.4134	.146	.219	.7555	.183
.155	.4572	.133	.222	.7714	.177
.170	.5333	.127	.226	.7976	.187
.177	.5719	.134	.231	.8189	.196
.184	.6073	.164	.235	.8401	.199
.191	.6464	.145	.240	.8665	.193
.200	.6929	.184	.252	.9299	.196
.207	.7288	.197	.257	.9563	.191
.214	.7669	.226	.261	.9775	.214
.225	.8260	.208	.266	.0039	.198
.233	.8651	.219	.270	.0250	.197
.240	.9069	.187	.276	.0567	.184
.253	.9734	.196	.280	.0778	.174
.260	.0083	.206	.286	.1098	.196
.267	.0448	.196	.298	.1729	.145
.273	.0786	.202	.303	.1994	.172
.279	.1119	.215	.308	.2258	.165
.286	.1468	.180	.314	.2575	.157
644.178	.8592	.202	926.137	.6058	.161
.185	.8972	.198	.141	.6270	.135
.192	.9326	.213	.146	.6534	.131
.200	.9743	.212	.150	.6745	.161
.206	.0076	.222	.159	.7221	.145
.213	.0435	.227	.163	.7432	.158
.220	.0811	.217	.167	.7643	.155
.227	.1191	.187	.172	.7908	.180
.234	.1577	.188	.177	.8172	.217
.243	.2015	.201	.181	.8383	.231
.249	.2375	.186	.185	.8595	.214
.257	.2771	.155	.190	.8859	.209
.264	.3130	.138	.198	.9281	.193
.271	.3537	.124	.203	.9546	.204
.278	.3891	.165	.207	.9757	.189
.285	.4255	.105	.211	.9968	.192
.291	.4594	.109	.251	.2082	.153
915.184	0.7351	-0.147	926.256	0.2346	-0.166

Table 1c — concluded.

JD(Hel)	Phase	ΔV	JD(Hel)	Phase	ΔV
926.260	0.2557	-0^m.146	319.200	0.3753	-0^m.164
.265	.2821	.135	.201	.3790	.169
.274	.3297	.122	.209	.4202	.185
.279	.3561	.124	.213	.4435	.149
.284	.3825	.154	.216	.4604	.152
928.159	.2892	.172	.230	.5349	.119
.170	.3473	.152	.236	.5650	.175
.180	.4001	.143	.244	.6073	.183
.189	.4477	.121	.253	.6538	.159
.203	.5217	.139	.257	.6776	.175
.214	.5798	.158	.260	.6923	.140
.224	.6326	.166	.272	.7557	.146
.238	.7066	.157	.278	.7859	.163
.249	.7647	.187	.279	.7901	.162
.275	.9021	.197	.284	.8207	.147
.285	.9549	.207	.295	.8762	.180
.301	.0395	.221	.299	.8995	.151
.311	.0923	.195	.314	.9745	.213
2445			.323	.0236	.245
319.119	.9469	.239	.327	.0453	.221
.132	.0129	.206	.331	.0791	.221
.142	.0658	.190	.337	.0960	.231
.149	.1012	.204	.340	.1124	.203
.158	.1540	.199	.343	.1325	.205
.170	.2147	.165	.355	.1922	.203
.181	.2765	.158	.356	.1985	.214
.190	.3241	.171	.360	.2196	.216
319.197	0.3383	-0.167	319.368	0.2640	-0.203

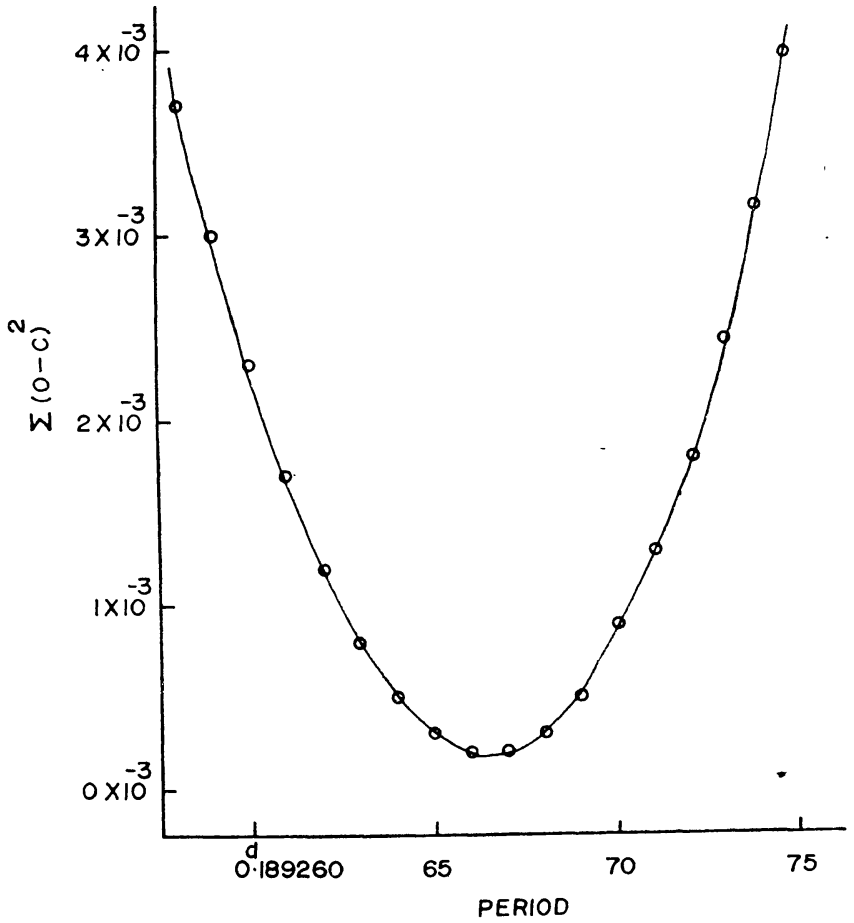

Fig. 2. The sum of the square residuals, $\Sigma(O-C)^2$ plotted against the assumed values of period for HD 37819.

Table 2

The residuals $O-C$ from different elements of HD 37819

Times of Maxima Observed by Present authors.	$(O-C)$ with period 0^d 18916 (Burki and Mayor 1981)	$(O-C)$ with period 0^d 1892666 (present authors)
2444620.1675		
643.2585	0^d0132	0^d0000
644.2028	0.0113	−0.0019
915.2330	0.0720	−0.0019
925.2610	−0.0455	−0.0038
926.2060	−0.0569	−0.0038
928.2915	−0.0341	−0.0019
2445319.1328	0.0379	0.0057
319.3220	0.0379	0.0057
322.1552	0.0303	0.0000

The normal differential colours $\Delta(U-B)$ and $\Delta(B-V)$ determined at various phases covering the whole cycle are listed in Table 3 and the corresponding colour curves are shown in Figure 3. The $\Delta(B-V)$ versus $\Delta(U-B)$ diagram obtained from smoothed normal colour curves is also shown in Figure 3.

Table 3

Normal differential colours of HD 37819

Phase	Δ(B-V)	Δ(U-B)	Phase	Δ(B-V)	Δ(U-B)
0.012	0^m414	0^m077	0.574	0^m465	0^m086
.041	.420	.082	.648	.460	.071
.062	.404	.098	.753	.443	.072
.087	.412	.086	.813	.434	.078
.145	.428	.076	.838	.438	.099
.246	.437	.096	.863	.424	.077
.332	.451	.083	.889	.401	.091
.374	.462	.081	.917	.410	.091
.426	.454	.094	.940	.404	.084
.467	.458	.085	.967	.393	.090
0.526	0.446	0.101	0.987	0.401	0.101

4. Discussion and conclusions

The UBV light curves (Fig. 1) of the star under study appear to be symmetrical in shape, and no appreciable change in the amplitude of the light variation is found in the individual light curves. This indicates that there exists no secondary period. The scatter which appears in the comprehensive light curves is a result of combining individual light curves. Individual light curves have scatter comparable to that of the comprehen-

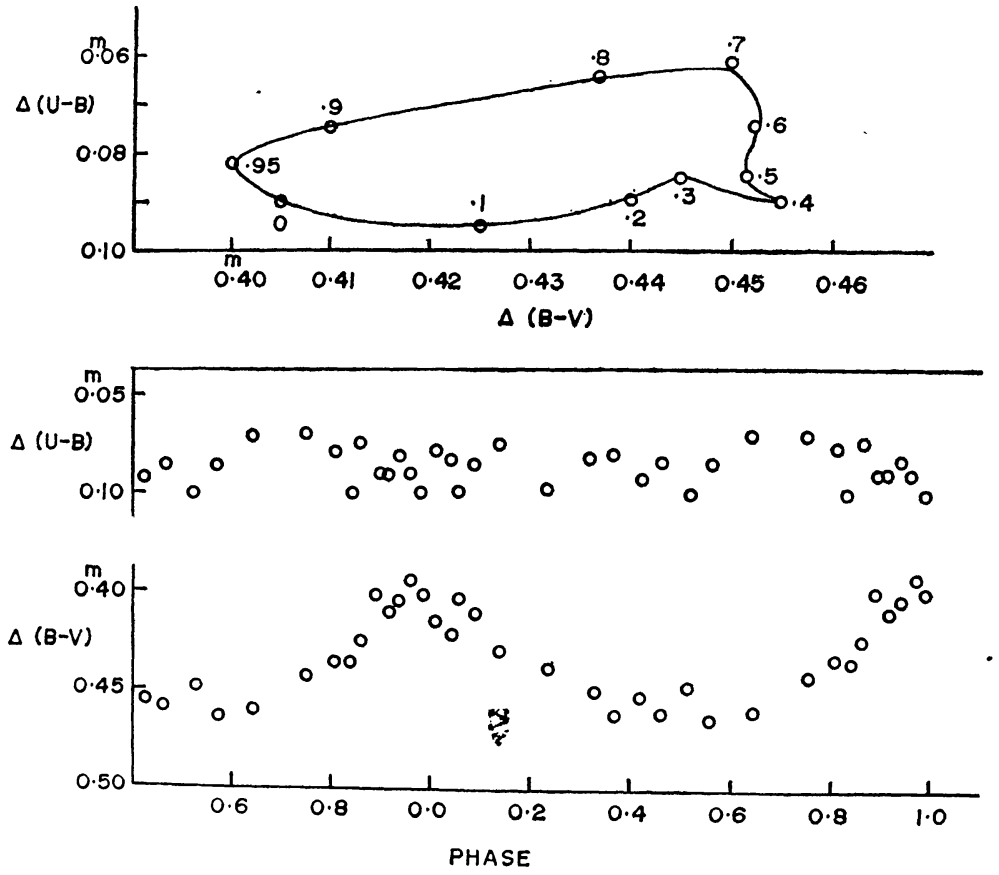

Fig. 3. Colour-colour diagram at different phases and normal colour curves plotted against phase of HD 37819.

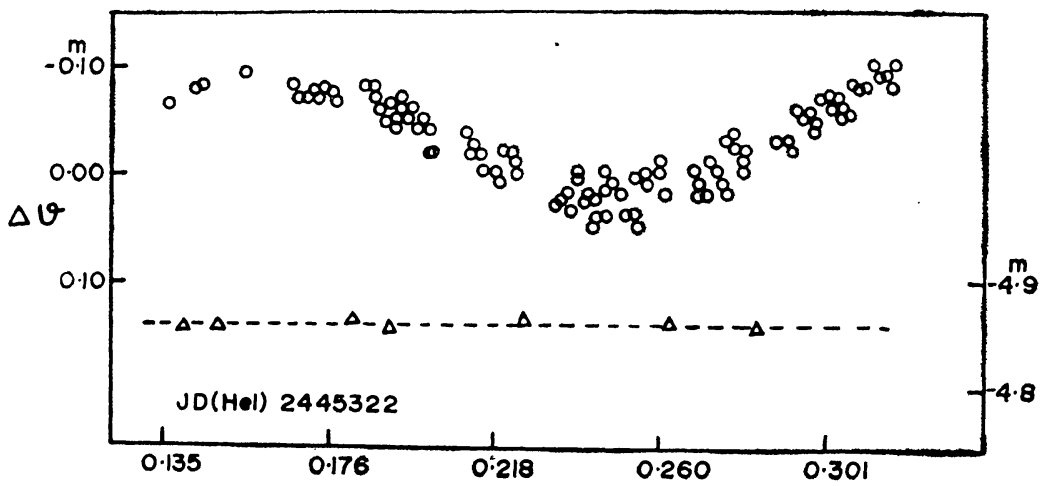

Fig. 4. Individual observations in V filter on the night of JD 2445322. Below this, the instrumental magnitude of the comparison star used, is also shown.

sive light curves. To show this a typical individual light curve (in instrumental system) in V magnitude is shown in Figure 4, the variation of comparison star is also shown below the light curve of the variable star. The amplitude variation in the U, B and V comprehensive light curves are $0^m.15$, $0^m.12$ and $0^m.08$ respectively.

The $B-V$ colour varies in phase with V magnitude while the $U-B$ colour appears to vary in opposite phase. The mean values of $B-V$ and $U-B$ colours are read out to be $0^m.53$ and $0^m.15$ respectively. The mean visual magnitude averaged over the whole pulsation cycle is $7^m.85$. According to the spectral class F4III (Burki and Mayor, 1980) the intrinsic $B-V$ and $U-B$ colours are $0^m.39$ and $0^m.07$, respectively (Golay 1974). The reddenings in $B-V$ and $U-B$ colours for this star are therefore $0^m.14$ and $0^m.08$ respectively.

The $\Delta(B-V)$ versus $\Delta(U-B)$ diagram obtained from smoothed normal colour curves is shown in Figure 3. The curve reveals that during the rise of brightness in the light curves from phase 0.4 to 0.7, there is rapid change ($0^m.09$ to $0^m.05$) in $U-B$ colour. In this duration there is no appreciable change in $B-V$ colour. From phase 0.7 to 0.95 the $B-V$ colour changes from $0^m.45$ to $0^m.40$, while the $U-B$ varies from $0^m.065$ to $0^m.085$. From phase 0.95 to 0.40 there is no appreciable change in $U-B$ but the $B-V$ colour varies from $0^m.40$ to $0^m.45$.

The pulsation constant (Q) is derived to be $0^d.035$ which indicates that the star is a radial pulsator (Dziembowski, 1980) and pulsates in the fundamental mode. The effective temperature is derived to be 6800 K from Tsvetkov's (1977) P-L-C relation, based on linear nonadiabatic model calculations for δ Scuti stars pulsating in the fundamental mode. By applying the reddening correction of $0^m.14$, the absolute magnitude is derived to be $1^m.03 \pm 0.16$ from P-L-C relation given by Gupta (1978) for δ Scuti stars pulsating in the fundamental mode. When plotting in the colour magnitude diagram, the star lies near the red edge of the cepheid instability strip where the fundamental period is prominent in the pulsation of cool δ Scuti stars. This furthen supports that the period of $0^d.1892666$ is fundamental. Moreover 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 $2M_\odot$ (Breger, 1979). From the relations given by McNamara and Feltz (1978) for dwarf cepheids, the mean effective gravity ($\log g$), radius (R) and mass (M) of the star are derived to be 3.6, 3.9 ($R_\odot$) and 1.8 $M_\odot$, respectively.

The short period, shape of the light and colour curves and physical parameters put the star among the dwarf cepheid variables and in the giant phase of evolution.

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