STUDY OF THE DELTA-SCUTI STAR HR 1170

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Abstract. The light and colour curves of the δ-Scuti star HR 1170 are presented. The absolute and bolometric magnitudes are derived and the position of the star on the colour-colour diagram is also shown. The primary and beat periods estimated from the light curves are $0\overset{d}{.}098\,299$ and $0\overset{d}{.}392\,06$, respectively.

1. Introduction

The δ-Scuti star HR 1170 [$\alpha(1900)=3^h42^m14^s$, $\delta(1900)=+43°39'$, $m(v)=5\overset{m}{.}85$, spectral class F_0] was first reported as a variable by Breger (1969). He estimated its period $\simeq 0\overset{d}{.}097$ with an amplitude variation $\simeq 0\overset{m}{.}08$. In this paper we present the light and colour curves and the fundamental and beat periods of the star and also estimates of its temperature and mass.

2. Observations

The observations were made at Naini Tal on nine nights between 10 November, 1974 through 18 December, 1975 on the 38-cm Cassegrain reflector using a cooled 1P21 photomultiplier tube and the *UBV* filters of the Johnson and Morgan system. The stars HR 1130 and HR 1141 were taken as comparison stars, except for the last three nights, on which only the first of these stars was observed. The standard deviation of the observed magnitudes of the comparison stars in *UBV* has a range of $0\overset{m}{.}007$–$0\overset{m}{.}01$, $0\overset{m}{.}005$–$0\overset{m}{.}006$, $0\overset{m}{.}005$–$0\overset{m}{.}007$ respectively which is a measure of the precision of the observations. The observations were reduced to the standard *UBV* system. The V observations as also the computed $B-V$, $U-B$ colours are listed in Table I and the light and the colour curves are plotted respectively in Figures 1 and 3.

3. Period

Breger (1974) on the basis of his observations on eight nights in September–October 1973 had estimated the presence of two periods in the star measuring about $0\overset{d}{.}097$ and $0\overset{d}{.}067$. The light curves obtained by us (Figure 1) show a variable amplitude and suggest a beat phenomenon. By combining the observations by Breger with ours we have derived respectively from the maxima and the minima of the light curves, two separate estimates of the primary period to be $0\overset{d}{.}098\,299 \pm 0\overset{d}{.}000\,001$ and $0\overset{d}{.}098\,300 \pm 0\overset{d}{.}000\,001$, respectively, which are internally consistent. The beat period estimated from the light curves is $0\overset{d}{.}392\,06$.

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TABLE I

Helioc J.D. 2 442 000+	V	$B-V$	$U-B$	Helioc J.D. 2 442 000+	V	$B-V$	$U-B$
362.220	5.871	0.291	0.071	369.155	5.882	0.315	0.055
362.230	5.809	0.276	0.083	369.165	5.901	0.323	0.062
362.239	5.780	0.272	0.085	369.175	5.917	0.306	0.057
362.253	5.802	0.284	0.063	369.187	5.858	0.299	0.062
362.262	5.821	0.286	0.071	369.196	5.791	0.303	0.070
362.271	5.848	0.291	0.068	369.205	5.770	0.278	0.095
362.281	5.869	0.307	0.052	369.214	5.780	0.276	0.078
362.290	5.880	0.315	0.055	369.224	5.832	0.279	0.091
362.298	5.881	0.310	0.059	369.233	5.878	0.299	0.057
362.313	5.888	0.291	0.066	369.241	5.901	0.290	0.068
362.322	5.880	0.285	0.058	369.250	5.890	0.330	0.045
362.332	5.860	0.286	0.075	369.258	5.887	0.311	0.045
362.343	5.851	0.278	0.077	369.266	5.870	0.308	0.046
362.353	5.857	0.284	0.077	369.274	5.860	0.290	0.059
363.141	5.796	—	—	369.286	5.831	0.282	0.071
363.150	5.814	—	—	369.297	5.793	0.303	0.083
363.160	5.795	0.329	—	369.307	5.820	0.278	0.087
363.170	5.844	0.314	—	369.315	5.822	0.295	0.087
363.180	5.873	0.321	—	369.324	5.850	0.312	0.063
363.190	5.874	0.308	0.083	369.333	5.901	0.319	0.055
363.199	5.876	0.318	0.078	374.096	5.851	0.281	0.074
363.208	5.876	0.310	0.082	374.105	5.880	0.311	0.053
363.218	5.859	0.307	0.071	374.114	5.900	0.306	0.064
363.227	5.830	0.308	0.088	374.123	5.902	0.286	0.087
363.236	5.812	0.295	0.080	374.131	5.912	0.300	0.077
363.246	5.793	0.304	0.091	374.139	5.890	0.305	0.068
363.255	5.797	0.304	0.074	374.148	5.862	0.281	0.055
363.264	5.842	0.302	0.076	374.156	5.825	0.300	0.069
363.276	5.862	0.336	0.052	374.165	5.802	0.292	0.071
363.285	5.892	0.322	0.073	374.173	5.800	0.298	0.074
363.294	5.901	0.318	0.070	374.182	5.821	0.305	0.077
363.302	5.885	0.314	0.059	374.190	5.850	0.313	0.071
363.309	5.856	0.299	0.070	374.198	5.858	0.316	0.068
363.329	5.817	0.306	0.071	374.206	5.879	0.328	0.060
363.340	5.804	0.308	0.078	374.219	5.900	0.326	0.049
363.348	5.812	0.310	0.079	374.227	5.898	0.315	0.048
363.356	5.836	0.316	0.060	374.238	5.880	0.305	0.052
363.366	5.860	0.331	0.051	374.248	5.851	0.290	0.050
363.375	5.889	0.334	0.065	374.256	5.832	0.283	0.056
363.384	5.902	0.345	0.044	374.263	5.811	0.288	0.064
363.393	5.883	0.362	0.040	374.271	5.820	0.292	—
363.403	5.886	0.326	0.055	374.278	5.851	0.289	—
363.413	5.843	0.314	0.057	379.239	5.801	0.301	—
363.423	5.810	0.302	0.075	379.250	5.810	0.294	0.079
369.132	5.831	0.314	0.095	379.259	5.815	0.304	0.070
369.145	5.840	0.320	0.080	379.272	5.858	0.305	0.067

Table I (Continued)

Helioc J.D. 2 442 000+	*V*	*B−V*	*U−B*
379.280	5.870	0.294	0.074
379.287	5.861	0.316	0.062
379.296	5.877	0.306	0.074
379.304	5.870	0.310	0.062
379.313	5.861	0.305	0.072
379.322	5.849	0.303	0.077
379.329	5.838	0.299	0.076
379.338	5.830	0.302	0.069
379.346	5.810	0.286	0.074
379.355	5.813	0.285	0.087
379.365	5.838	0.291	0.074
379.374	5.840	0.303	0.072
379.382	5.859	0.320	0.086
379.389	5.890	0.307	0.061
379.397	5.910	0.305	0.070
379.405	5.901	0.298	0.073
402.080	5.790	0.314	0.060
402.088	5.805	0.311	0.070
402.095	5.814	0.302	0.083
402.103	5.824	0.290	0.077
402.110	5.805	0.301	0.077
402.118	5.857	0.304	0.075
402.133	5.896	0.307	0.074
402.141	5.909	0.326	0.052
402.160	5.887	0.323	—
402.167	5.885	0.318	0.065
402.174	5.863	0.309	0.060
402.181	5.849	0.301	0.062
402.188	5.841	0.294	0.054
402.195	5.833	—	—
739.060	5.864	—	
739.072	5.885	—	
739.077	5.897	—	
739.087	5.899	0.302	
739.092	5.898	0.308	
739.096	5.891	0.308	
739.101	5.881	0.295	
739.106	5.870	0.298	
739.110	5.845	0.290	
739.115	5.828	0.279	
739.120	5.813	0.274	
739.125	5.800	0.277	
739.130	5.798	0.274	
739.135	5.803	0.280	
739.140	5.827	0.278	
739.145	5.834	0.287	
739.150	5.839	0.302	
739.155	5.857	0.304	
739.160	5.868	0.311	
739.165	5.880	0.309	
739.172	5.892	0.305	
739.177	5.899	0.307	
739.182	5.902	0.315	
739.187	5.909	0.311	
739.193	5.884	0.301	
739.198	5.873	0.302	
739.202	5.856	0.285	
739.207	5.850	0.287	
739.212	5.819	0.278	
739.217	5.805	0.273	
739.222	5.800	0.277	
739.226	5.786	0.290	
739.231	5.779	0.291	
739.236	5.799	0.307	
739.240	5.800	0.293	
739.245	5.827	0.305	
739.250	5.839	0.311	
739.255	5.862	0.310	
739.259	5.876	0.310	
739.264	5.896	0.308	
739.269	5.905	0.311	
739.274	5.904	0.308	
739.279	5.901	0.296	
739.285	5.885	0.292	
739.289	5.890	0.276	
739.295	5.893	0.283	
739.300	5.864	0.279	
739.305	5.852	0.277	
739.309	5.835	0.276	
739.314	5.824	0.278	
739.319	5.814	0.281	
739.323	5.818	0.282	
739.328	5.816	0.294	
739.332	5.821	0.295	
739.337	5.834	0.298	
739.342	5.853	0.307	
739.346	5.882	0.307	
739.350	5.896	0.304	
739.355	5.908	0.309	
739.359	5.909	0.305	
739.364	5.914	0.304	
739.369	5.908	0.302	
739.374	5.913	0.290	
739.378	5.900	0.293	
739.382	5.894	0.288	
739.387	5.886	0.291	

Table I (Continued)

Helioc J.D. 2 442 000+	V	$B-V$	Helioc J.D. 2 442 000+	V	$B-V$
739.391	5.878	0.300	756.357	5.878	0.313
739.396	5.867	0.293	756.362	5.897	0.324
739.401	5.881	0.297	756.367	5.902	0.303
739.405	5.882	0.299	756.372	5.904	0.323
739.410	5.874	0.286	756.377	5.896	0.315
739.414	5.881	0.291	756.382	5.891	0.304
739.419	5.878	0.304	756.388	5.878	0.287
739.424	5.871	0.307	756.393	5.868	0.284
739.428	5.868	0.292	756.398	5.858	0.285
739.433	5.866	0.309	756.403	5.828	0.297
739.437	5.875	0.301	756.407	5.821	0.286
739.441	5.870	0.310	756.412	5.803	0.290
739.446	5.864	0.306	756.417	5.801	0.269
739.451	5.863	—	756.425	5.776	0.277
739.455	5.876	—	756.429	5.783	—
739.460	5.868	—	756.432	5.787	—
739.464	5.875	—	756.438	5.801	—
739.468	5.875	—	765.085	5.825	0.317
739.473	5.860	—	765.090	5.846	0.327
739.477	5.868	—	765.094	5.879	0.312
739.482	5.864	—	765.098	5.889	0.327
739.486	5.849	—	765.103	5.892	0.317
756.218	5.819	0.326	765.107	5.901	0.308
756.223	5.827	0.310	765.111	5.891	0.319
756.228	5.823	0.310	765.115	5.891	0.317
756.233	5.836	0.285	765.119	5.892	0.306
756.238	5.837	0.307	765.124	5.887	0.307
756.243	5.836	0.308	765.128	5.873	0.298
756.248	5.847	0.297	765.132	5.864	0.302
756.251	5.844	0.295	765.136	5.871	0.268
756.257	5.849	0.294	765.140	5.826	0.285
756.263	5.849	0.297	765.144	5.814	0.291
756.270	5.852	0.309	765.148	5.812	0.278
756.276	5.867	0.313	765.152	5.808	0.287
756.281	5.871	0.314	765.156	5.813	0.284
756.287	5.889	0.313	765.160	5.792	0.302
756.291	5.893	0.311	765.164	5.796	0.311
756.297	5.885	0.310	765.180	5.842	0.313
756.305	5.875	0.292	765.188	5.839	0.317
756.311	5.843	0.300	765.192	5.852	0.323
756.316	5.826	0.294	765.196	5.871	0.316
756.321	5.809	0.285	765.201	5.873	0.319
756.326	5.796	0.295	765.206	5.872	0.321
756.331	5.800	0.291	765.210	5.871	0.315
756.336	5.816	0.311	765.215	5.892	0.312
756.342	5.830	0.314	765.221	5.883	0.314
756.347	5.845	0.317	765.226	5.880	0.317
756.352	5.868	0.328	765.231	5.867	0.310

Table I (Continued)

Helioc J.D. 2 442 000+	V	$B-V$	Helioc J.D. 2 442 000+	V	$B-V$
765.237	5.839	0.288	765.292	5.882	0.300
765.243	5.821	0.295	765.297	5.870	0.310
765.249	5.882	0.287	765.301	5.852	0.315
765.254	5.814	0.294	765.306	5.858	0.297
765.258	5.810	0.298	765.315	5.841	0.323
765.263	5.829	0.280	765.320	5.864	0.301
765.268	5.824	0.304	765.324	5.857	0.306
765.273	5.839	0.301	765.330	5.866	0.308
765.278	5.836	0.314	765.335	5.853	0.309
765.284	5.866	0.313	765.340	5.868	0.320
765.288	5.885	0.319	765.344	5.860	0.314

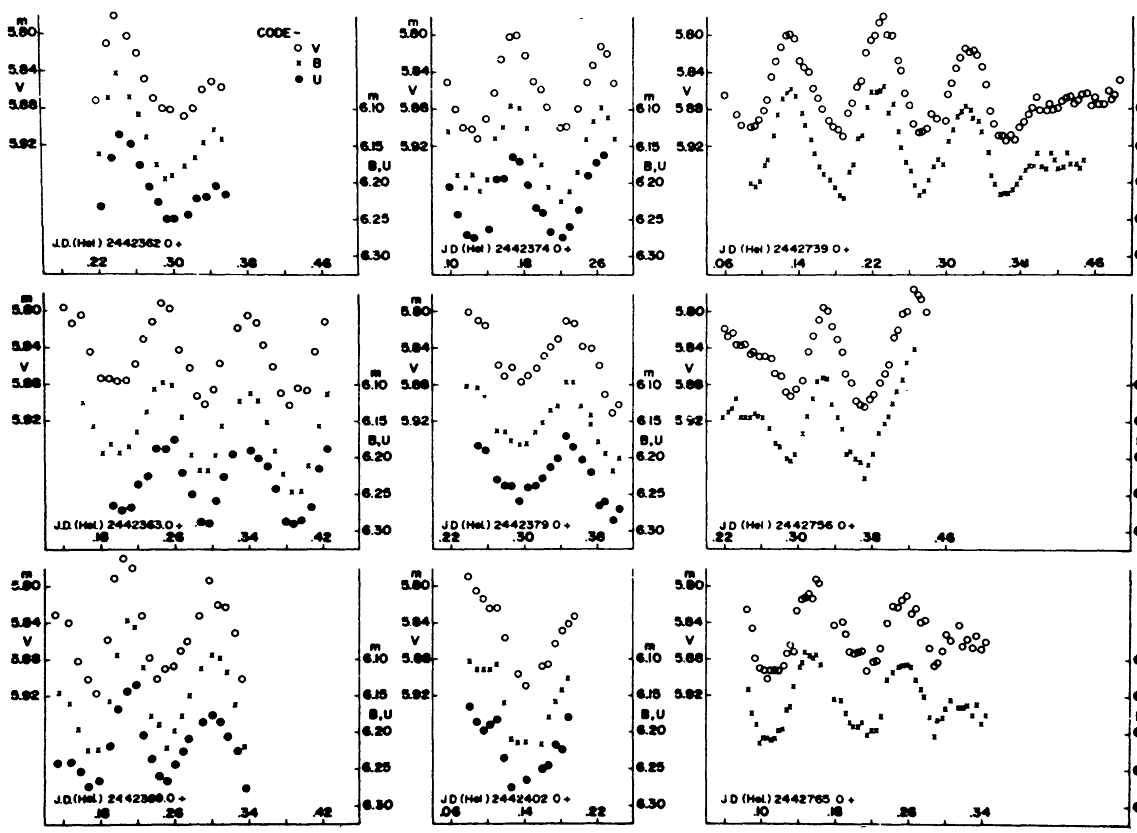

Fig. 1. The light curves for HR 1170 through U, B, V filters.

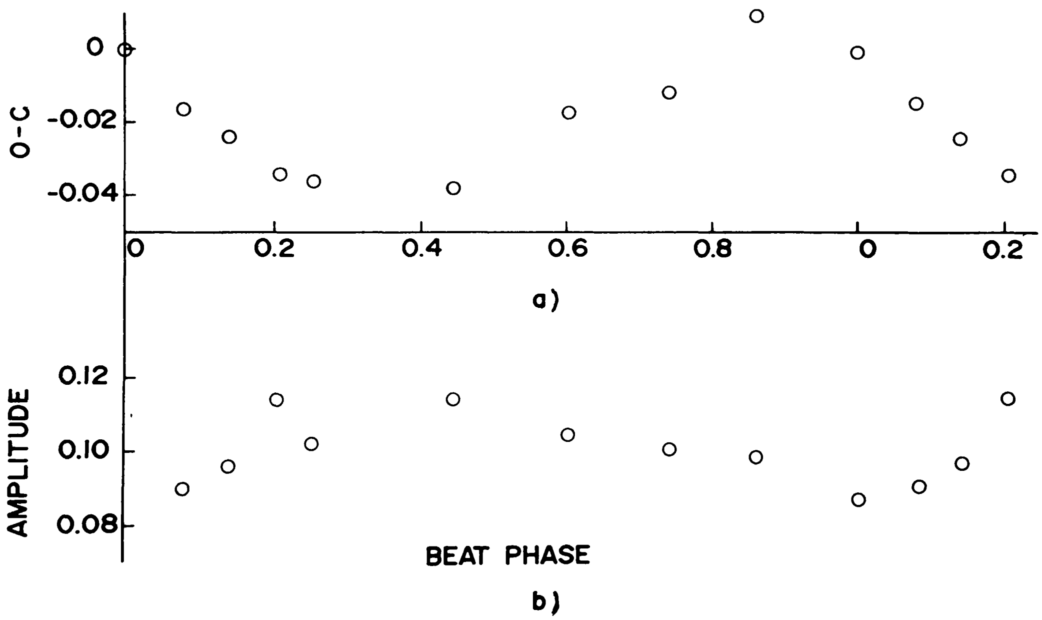

Fig. 2. A plot between beat phase versus (O–C) and beat phase versus amplitude of light variation for HR 1170.

A plot between beat phase versus (O–C) for the maxima (Figure 2a) and another between beat phase versus amplitude of light variation (Figure 2b) show that both the curves are sinusoidal and are nearly opposite in phase. From a comparison of these two curves we conclude that the secondary period, present in the pulsation, is longer than the primary period. Taking a beat period of $0\overset{d}{.}392\,06$ and one of the periods to be $0\overset{d}{.}098\,299$, the other period comes out to be $0\overset{d}{.}131\,192$. If we assume this as the fundamental period P_0 and $0\overset{d}{.}098\,299$ as a first overtone P_1, the period ratio $P_1/P_0 = 0.749$, which is in good agreement with the theoretical value of 0.75 for radial oscillation modes (Christy, 1966).

4. Discussion

From the colour curves, Figure 3, it appears that the $(B-V)$ colour of HR 1170 varies in phase with the V magnitude and is bluer at maximum than at minimum light while the $(U-B)$ colour varies in opposite phase with the V magnitude. The average variation in the amplitude of the $(B-V)$ colour during a pulsation is $\approx 0\overset{m}{.}03$. The mean values of $B-V$ and $U-B$ for the star determined from observations are $0\overset{m}{.}30 \pm 0\overset{m}{.}01$ and $0\overset{m}{.}07 \pm 0\overset{m}{.}01$ respectively.

In the colour-magnitude diagram given by Danziger and Dickens (1967), the star is located towards the red edge of the instability strip which indicates that the fundamental mode should be predominant in its pulsation. From the relation given by Breger (1975) the value of the pulsation constant Q is found to be $0\overset{d}{.}030 \pm 0\overset{d}{.}003$. Due to uncertainties in the values of the parameters (e.g., $\log g$, $T_{\rm eff}$, $M_{\rm bol}$) on which the value of Q is based, it is difficult to ascertain which mode of pulsation is predominant

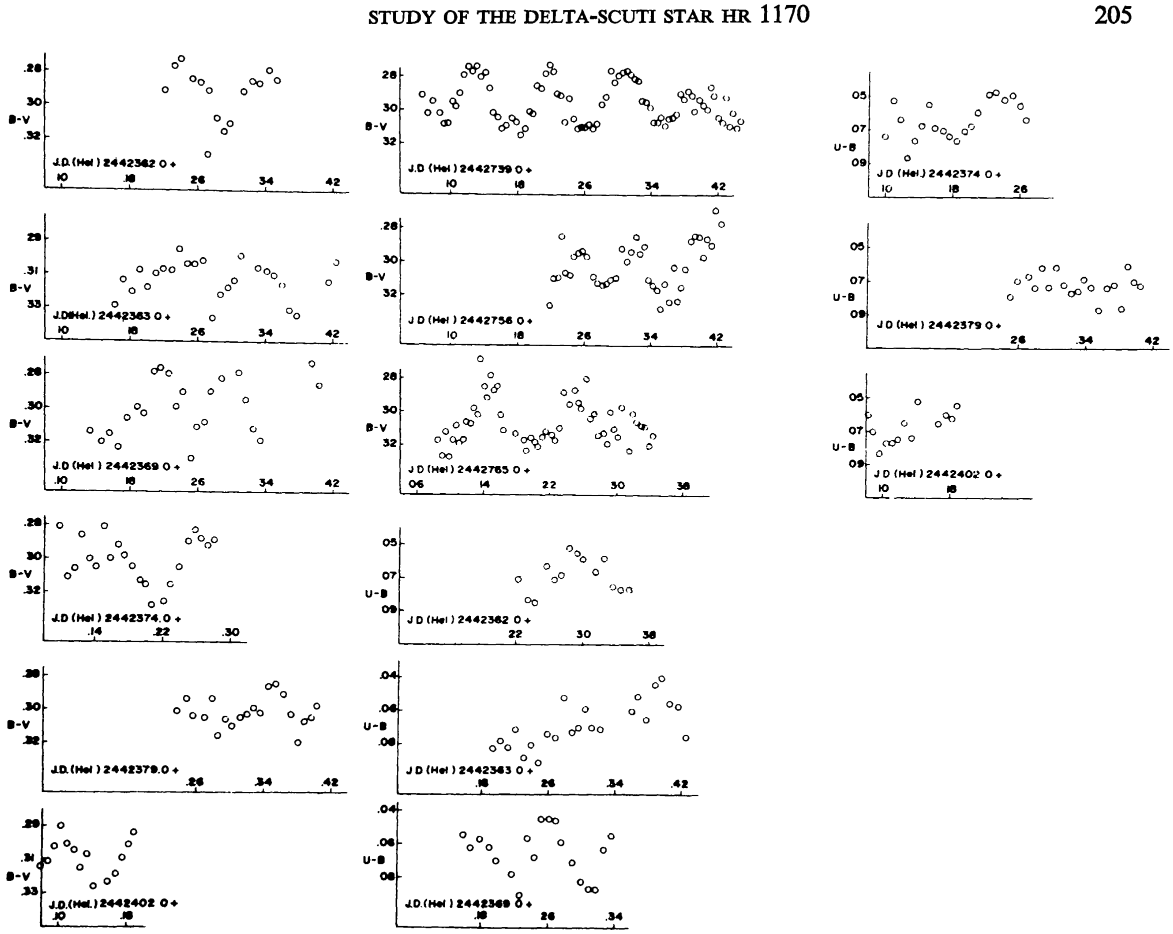

Fig. 3. Colour curves for HR 1170.

in this star. From Figure 2, however, it appears that the shorter period $0^{d}.098\,299$, i.e., the first overtone, is prominent in the pulsation.

On the colour-colour diagram (Figure 4) the position of HR 1170 is in close proximity to the ZAMS although most of the δ-Scuti stars lie below the ZAMS (Danziger and Dickens, 1967). The position of the stars in this diagram is influenced by effective temperature, line blanketing and surface gravity. The star belongs to the luminosity class IV when plotted on the H-R diagram. Due to the low value of its $U-B$ colour as compared to other δ-Scuti stars, it seems that this star contains comparatively low metallic content.

Applying the *P-L-C* relation (Breger, 1975) and u, v, b, y photometric data (Baglin *et al.*, 1973), the absolute and bolometric magnitudes of the star are found to be $1^m.50 \pm 0^m.22$ and $1^m.24 \pm 0^m.23$ respectively. From the relation between colour and effective temperature (Fernie, 1964), the effective temperature of this star is derived to be 7485 K $\pm$ 65 K, which is close to the value of 7400 K found by Breger (1975). The mass of the star, derived from the theoretical evolutionary tracks for stars of 1.5 $M_{\odot}$ and 2.25 $M_{\odot}$ given by Iben (1967), is 1.8 $M_{\odot}$ which is quite in agreement with the value of 1.89 $M_{\odot}$ given by Peterson and Jorgenson (1972).

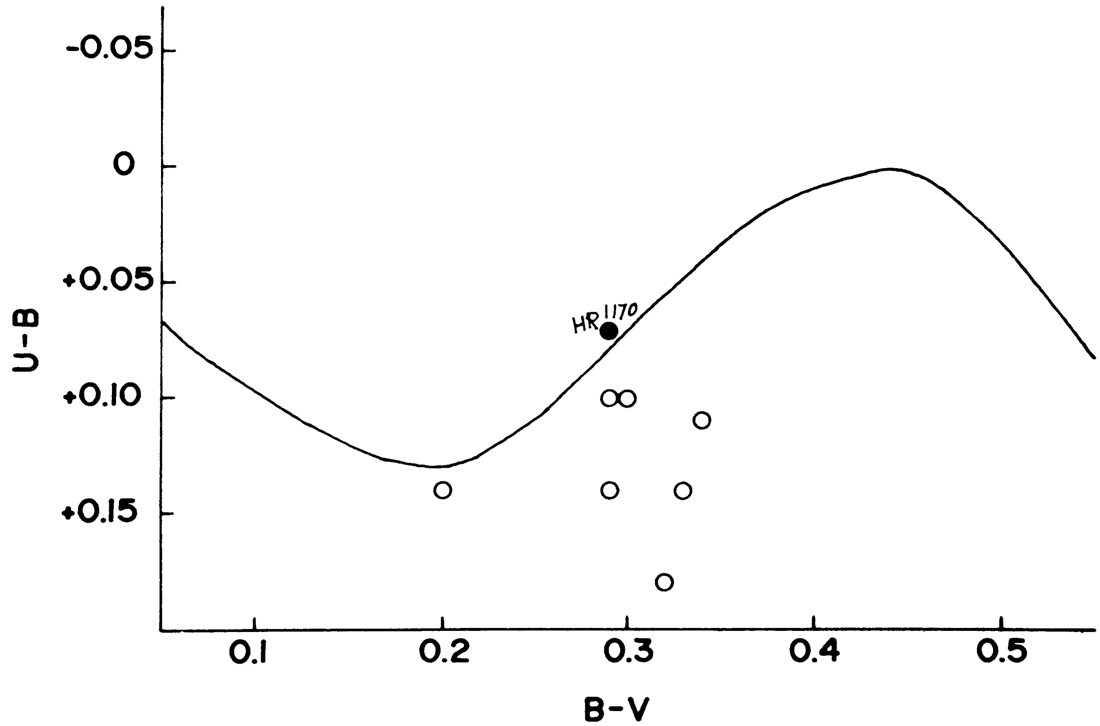

Fig. 4. The position of HR 1170 on the colour-colour diagram for δ-Scuti stars.

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