PHOTOELECTRIC STUDY OF THE δ SCUTI STAR HR 1225

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Abstract. The periodogram analysis of the V observations of the δ Scuti star HR 1225 has been carried out. Two frequencies of 6.415 cd ($P_0 = 0^d.1558$) and 8.418 cd ($P_1 = 0^d.1188$) have been determined. The period ratio of $P_1/P_0 = 0.762$ indicates radial pulsation. The absolute magnitude, effective temperature and mass of the star are derived to be $1^m.05$, 7600 K and 1.9 $M_\odot$, respectively.

1. Introduction

Jorgensen *et al.* (1971) have carried out the periodogram analysis of four night's observations of the δ Scuti star HR 1225 [$\alpha(1900) = 3^h51^m.8$, $\delta(1900) = -10°3'$, $V = 6^m.18$, sp: F0] and found a probable period of $0^d.1569$. After subtracting the contribution due to this period, the next period was found to be $0^d.1192$ or $0^d.1067$. Later on, in periodogram analysis, Jorgensen and Norgaard-Nielsen (1975) analysed the observations taken on 27, 31 Dec. 1972 and 1 Jan. 1973 and found a dominating period of $0^d.1562$ ($\nu_0 = 6.4$ cd) which agrees with the period 0.1569 determined by Jorgensen *et al.* (1971) and a next probable period of $0^d.0921$ ($\nu_1 = 10.85$ cd). However, Jorgensen and Norgaard-Nielsen (1975) found that together with these two frequencies (ν_0 and ν_1), the observed light curves of the star can also be well fitted to the other frequencies deviating by 1 cd in ν_1. Thus, different frequencies have been obtained from two different sets of observations taken at an interval of three years. We put this star on our U, B, V photometric system to see whether the frequencies present in the light variation of HR 1225 are stable or changing with time. On the basis of the results obtained by us, the pulsation characteristics of the star HR 1225 are discussed.

2. Observation

New photoelectric observations of the δ Scuti star HR 1225 were taken on nine nights during October 1977 to December 1978 on 38-cm Cassegrain reflector of the Uttar Pradesh State Observatory. A water cooled 1P21 photomultiplier tube and UBV filters of Johnson and Morgan system have been used during observations. Initially, two comparison stars HR 1217 and HR 1272 were observed on few nights. The star HR 1272 was found to be more stable than the former, with the standard deviation of $0^m.007$ in V filter. Hence, the subsequent observations and final reductions

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TABLE I

V magnitudes and colours of HR 1225

JD (Hel) 2443000 +	*V*	*B* − *V*	*U* − *B*	JD (Hel) 2443000 +	*V*	*B* − *V*	*U* − *B*
427.253	6m.201	0m.281		461.209	6m.164	0m.265	0m.144
0.259	6.191	0.274		0.216	6.154	0.261	0.140
0.266	6.196	0.268		0.225	6.157	0.266	0.138
0.272	6.172	0.268		0.233	6.157	0.262	0.142
0.278	6.179	0.268		0.241	6.170	0.267	0.145
0.285	6.165	0.264		0.248	6.168	0.276	0.142
0.292	6.159	0.266		0.257	6.176	0.273	0.145
0.299	6.161	0.258		0.265	6.181	0.274	0.140
0.307	6.157	0.260		0.273	6.173	0.280	0.144
0.313	6.162	0.265		0.281	6.177	0.279	0.140
0.329	6.168	0.277		0.288	6.178	0.275	0.135
0.337	6.179	0.287		0.296	6.185	0.284	0.138
0.343	6.191	0.282		0.303	6.193	0.286	0.130
0.349	6.205	0.287		0.312	6.187	0.288	0.126
456.197	6.190	0.289	0m.132	0.324	6.199	0.285	0.129
0.205	6.187	0.284	0.140	0.332	6.187	0.290	0.132
0.215	6.180	0.275	0.138	0.342	6.197	0.288	0.135
0.223	6.171	0.267	0.142	0.350	6.198	0.291	0.133
0.232	6.167	0.264	0.145	0.358	6.184	0.285	0.145
0.239	6.162	0.262	0.138	0.367	6.175	0.279	0.144
0.247	6.152	0.262	0.136	0.376	6.163	0.274	0.150
0.256	6.152	0.262	0.144	0.384	6.158	0.278	0.148
0.268	6.160	0.266	0.148	0.393	6.159	0.266	0.137
0.276	6.168	0.265	0.147	0.403	6.166	0.263	0.143
0.283	6.166	0.272	0.145	0.403	6.166	0.263	0.143
0.292	6.173	0.275	0.145	0.411	6.161	0.274	0.128
0.300	6.170	0.277	0.143	0.415	6.162	0.272	0.135
0.311	6.177	0.280	0.146	0.423	6.162	0.274	0.133
0.319	6.203	0.294	0.136	0.430	6.172	0.283	0.130
0.331	6.195	0.291	0.135	0.439	6.186	0.272	0.128
0.345	6.213	0.294	0.135	0.447	6.181	0.283	0.130
0.353	6.213	0.298	0.130	469.121	6.203	0.288	0.130
0.362	6.196	0.290	0.129	0.129	6.200	0.289	0.127
0.371	6.182	0.287	0.132	0.138	6.198	0.280	0.131
0.380	6.168	0.287	0.138	0.144	6.186	0.278	0.135
0.389	6.167	0.284	0.135	0.152	6.173	0.280	0.126
0.398	6.161	0.289	0.146	0.159	6.167	0.271	0.134
0.407	6.156	0.276	0.140	0.167	6.167	0.266	0.140
461.154	6.192	0.288	0.123	0.175	6.157	0.264	0.143
0.162	6.182	0.277	0.121	0.183	6.152	0.260	0.144
0.170	6.180	0.280	0.124	0.190	6.157	0.261	0.141
0.177	6.172	0.275	0.136	0.198	6.155	0.270	0.150
0.185	6.180	0.272	0.127	0.202	6.157	0.273	0.150
0.193	6.172	0.271	0.135	0.210	6.181	0.265	0.148
0.201	6.167	0.265	0.140	0.217	6.185	0.276	0.155

continued

Table I (continued)

JD (Hel) 2443000 +	V	$B-V$	$U-B$	JD (Hel) 2443000 +	V	$B-V$	$U-B$
469.225	6.180	0.289	0.150	840.228	6.166	0.264	0.146
0.232	6.192	0.291	0.155	0.235	6.171	0.261	0.151
0.240	6.200	0.293	0.147	0.241	6.170	0.259	0.145
0.247	6.196	0.296	0.145	0.248	6.168	0.263	0.151
0.255	6.200	0.286	0.140	0.255	6.171	0.266	0.142
0.263	6.204	0.289	0.133	0.263	6.177	0.274	0.140
0.270	6.196	0.286	0.130	0.269	6.181	0.278	0.133
0.277	6.192	0.277	0.129	0.276	6.200	0.278	0.140
0.286	6.192	0.287	0.129	0.284	6.192	0.283	0.137
0.294	6.180	0.273	0.131	0.291	6.198	0.280	0.141
0.301	6.172	0.283	0.140	852.112	6.174	0.272	0.144
0.308	6.170	0.280		0.119	6.182	0.270	0.146
0.317	6.162	0.275		0.125	6.173	0.273	0.146
803.228	6.163	0.260		0.131	6.176	0.275	0.144
0.233	6.164	0.259		0.137	6.179	0.277	0.147
0.238	6.158	0.253		0.142	6.187	0.273	0.137
0.244	6.157	0.255		0.148	6.189	0.282	0.144
0.251	6.152	0.252		0.155	6.192	0.286	0.133
0.257	6.150	0.251		0.161	6.186	0.284	0.139
0.263	6.156	0.255		0.167	6.182	0.275	0.140
0.268	6.163	0.264		0.173	6.179	0.280	0.141
0.273	6.166	0.260		0.179	6.179	0.271	0.138
0.279	6.164	0.268		0.185	6.163	0.274	0.140
0.285	6.162	0.270		0.191	6.160	0.270	0.145
0.291	6.171	0.273		0.197	6.161	0.268	0.147
0.296	6.175	0.276		0.204	6.154	0.261	0.141
0.302	6.180	0.272		0.209	6.158	0.263	0.143
0.308	6.179	0.274		0.215	6.157	0.267	0.134
0.315	6.186	0.280		0.221	6.164	0.271	0.144
0.320	6.195	0.283		0.228	6.162	0.281	0.132
0.326	6.201	0.280		0.234	6.165	0.279	0.129
0.333	6.201	0.282		0.240	6.174	0.281	0.127
0.340	6.206	0.283		0.246	6.182	0.286	0.125
0.346	6.193	0.279		0.253	6.181	0.289	0.127
0.353	6.197	0.279		0.262	6.201	0.292	0.122
0.359	6.184	0.270		0.269	6.198	0.293	0.121
0.364	6.194	0.268		0.275	6.198	0.285	0.126
0.370	6.168	0.261		0.282	6.187	0.277	0.124
0.375	6.153	0.259		0.289	6.198	0.271	0.135
0.380	6.161	0.262		0.296	6.192	0.271	0.138
840.178	6.198	0.273	0.146	0.303	6.179	0.264	0.143
0.185	6.200	0.274	0.139	0.310	6.163	0.267	0.150
0.192	6.202	0.275	0.145	0.316	6.173	0.262	
0.200	6.194	0.270	0.146	0.322	6.159	0.258	
0.207	6.192	0.268	0.147	0.329	6.150	0.257	
0.213	6.197	0.268	0.151	0.332	6.160	0.255	
0.220	6.178	0.260	0.150	855.226	6.183	0.278	

continued

Table I (continued)

JD (Hel) 2443000 +	V	$B-V$	$U-B$	JD (Hel) 2443000 +	V	$B-V$	$U-B$
855.230	6m191	0m275		860.148	6m172	0m262	
0.235	6.183	0.286		0.153	6.166	0.263	
0.239	6.196	0.277		0.157	6.169	0.262	
0.244	6.189	0.282		0.162	6.167	0.256	
0.249	6.192	0.286		0.166	6.166	0.259	
0.254	6.186	0.275		0.171	6.169	0.255	
0.258	6.193	0.271		0.175	6.166	0.261	
0.262	6.184	0.273		0.180	6.167	0.260	
0.268	6.184	0.268		0.185	6.176	0.263	
0.272	6.180	0.274		0.189	6.174	0.274	
0.278	6.183	0.268		0.194	6.174	0.275	
0.283	6.174	0.264		0.198	6.170	0.274	
0.289	6.179	0.262		0.202	6.177	0.281	
0.294	6.179	0.260		0.206	6.178	0.280	
0.299	6.173	0.257		0.211	6.183	0.279	
0.303	6.161	0.255		0.215	6.185	0.282	
0.308	6.166	0.254		0.220	6.189	0.279	
0.313	6.162	0.254		0.224	6.188	0.281	
0.318	6.161	0.260		0.229	6.190	0.285	
0.323	6.163	0.263		0.233	6.192	0.288	
0.328	6.158	0.274		0.238	6.193	0.283	
0.333	6.170	0.270		0.242	6.185	0.280	
0.338	6.164	0.271		0.246	6.186	0.281	
0.342	6.166	0.272		0.251	6.174	0.280	
0.347	6.176	0.285		0.255	6.173	0.269	
0.352	6.176	0.283		0.260	6.172	0.267	
0.356	6.179	0.279		0.264	6.173	0.262	
0.361	6.187	0.281		0.269	6.167	0.261	
0.365	6.196	0.190		0.274	6.164	0.260	
860.130	6.182	0.272		0.278	6.161	0.254	
0.135	6.185	0.270		0.284	6.171	0.258	
0.140	6.180	0.269		0.289	6.169	0.263	
0.144	6.186	0.268					

were done using the star HR 1272 only. The magnitude were corrected for extinction using nightly extinction coefficients. By use of the transformation equations

$$\Delta V = \Delta v_i - 0.116\,\Delta(B - V),$$

$$\Delta(B - V) = 1.010\,\Delta(b - v)_i,$$

$$\Delta(U - B) = 1.086\,\Delta(u - b)_i,$$

the instrumental magnitudes and colour indices were transformed to the standard U, B, V system (Gupta, 1979).

The photoelectric parameters V, B–V and U–B of the variable star HR 1225, are tabulated in Table I and the V light curves and B–V colour curves are plotted in Figure 1.

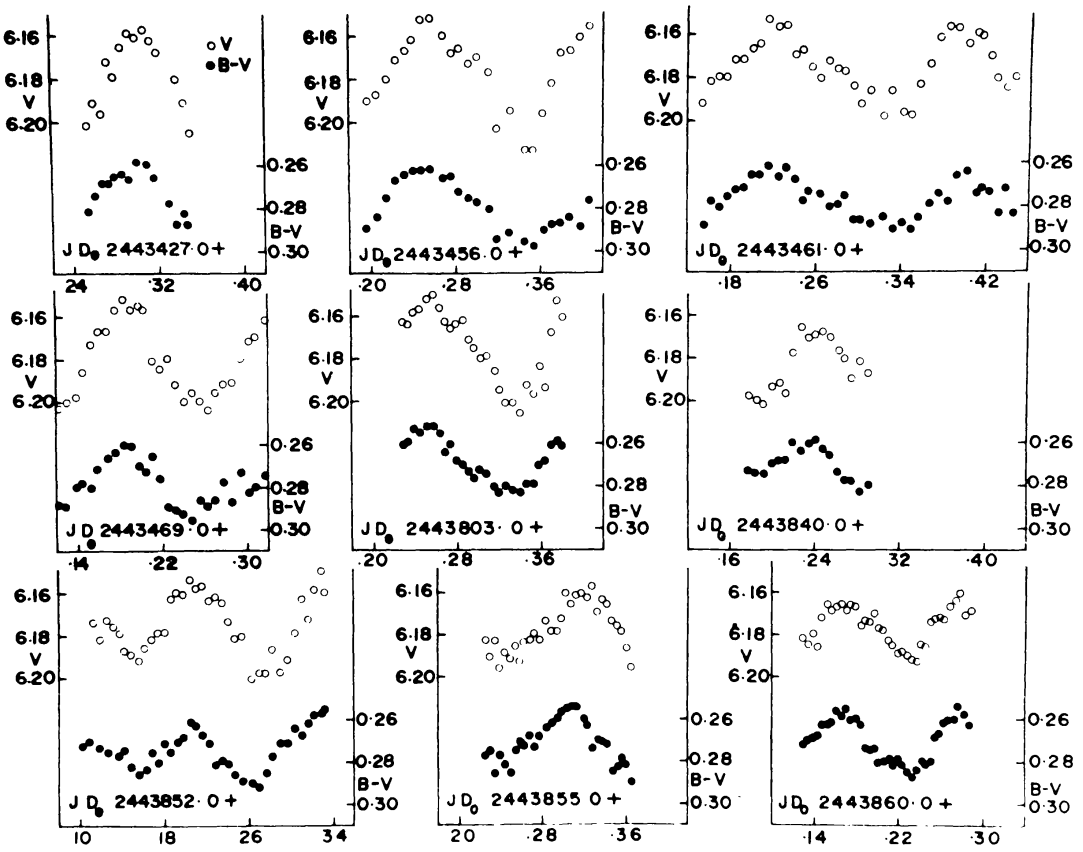

Fig. 1. Light and colour curves of HR 1225.

3. Period

The light curves of HR 1225 show light variations of non-periodic character. The light amplitude varies from cycle to cycle. Hence, the observations cannot be represented by a single periodic oscillation.

To determine the frequencies present in the light variations, the periodogram analysis and the least-squares method, as described in an earlier paper by Gupta (1979), have been employed to analyse the V observations. In the periodogram analysis, the largest peaks are found to be $\nu_0 = 6.415$ cd (Figure 2) and $\nu_1 = 8.418$ cd (Figure 3) which correspond to the primary period of $0^d.1558$ and secondary period of $0^d.1188$ respectively. These values are close to the values of the primary period of $0^d.155\,879$ (Figure 4) and the secondary period of $0^d.118\,795$ (Figure 5) determined by least-squares solution. The first frequency $\nu_0 = 6.415$ cd determined by us, is in fair agreement with the value $\nu_0 = 6.40$ cd obtained by Jorgensen and Norgaard-Nielsen (1975) while the second frequency $\nu_1 = 8.418$ cd differs considerably. However, our estimates of the primary and secondary period are close to the values of the primary period $0^d.1569$ and secondary period $0^d.1192$ respectively, determined by Jorgensen *et al.* (1971). Thus, it indicates that the frequencies present in the light variations of HR 1225 are stable and not changing with the time.

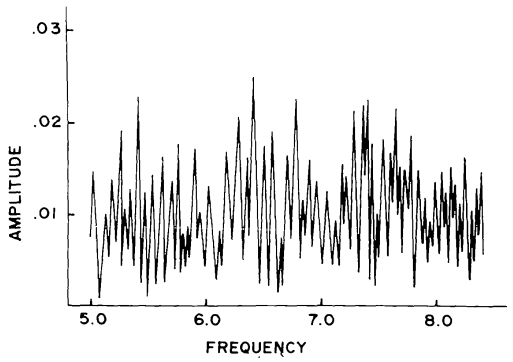

Fig. 2. Periodogram analysis for HR 1225 using V observations.

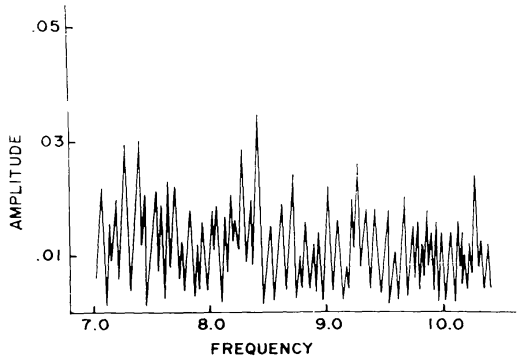

Fig. 3. Periodogram analysis of the residuals, for HR 1225 after subtraction of the peak at 6.415 cd.

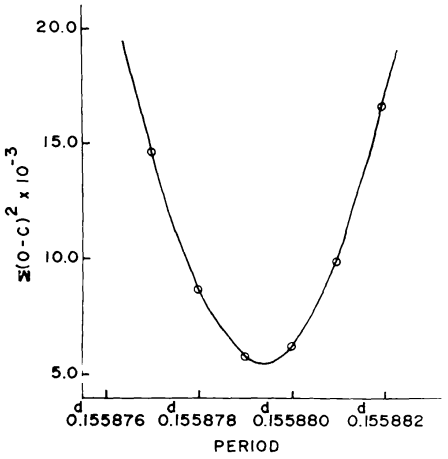

Fig. 4. Plot between trial values of primary period versus $\sum(O - C)^2$ for HR 1225.

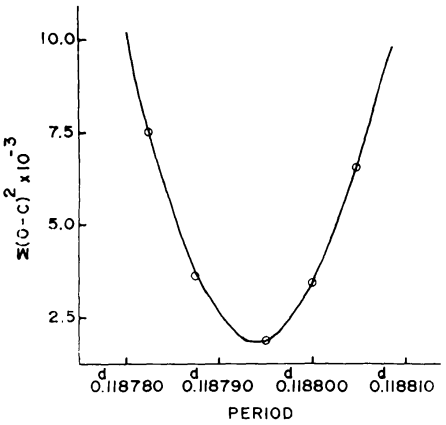

Fig. 5. Plot between trial values of secondary period versus $\sum(O - C)^2$ for HR 1225.

4. Discussion

The (B–V) colour curves of the δ Scuti star HR 1225 are well correlated with the V light curves and are bluer at maximum than at minimum light as shown in Figure 1. The maximum variations in the V magnitude and B–V colour, during a pulsation period, are found to be $\simeq 0^{m}.05$ and $0^{m}.03$ respectively. The mean values of the V magnitude and B–V colour are derived to be $6^{m}.18$ and $+0^{m}.28$ respectively, which are in fair agreement with the values given by Lake (1962) and Hoffleit (1964). The mean value of U–B is derived to be $+0^{m}.14$.

The improved P-L-C relations (Gupta, 1978) applicable for the δ Scuti variables have been used to derive the absolute magnitude of $1^{m}.05$ for HR 1225 while from *uvby β* calibrations, the absolute magnitude is derived to be $1^{m}.29$ (Breger and Bregman, 1975). Applying the bolometric correction of $-0^{m}.06$ (Allen, 1973), the bolometric magnitude is derived to be $0^{m}.99$.

Using the (B–V) – (b–y) calibration (Golay, 1972) and T_e – (b–y) calibration (Breger, 1975) the effective temperature (T_e) of the star HR 1225 is derived to be

7600 K which is consistent with the *uvby β* photometric value 7600 K (Breger and Bregman, 1975). The value of the surface gravity ($\log g$) is derived from the c_1–$(b-y)$ calibration given by Breger (1974) for A and F stars of population I, where c_1 and $(b-y)$ indices are calibrated in terms of $\log g$ and T_e by the use of ATLAS model atmospheres.

Further, using the period of $0^d.1558$ and the related parameters (i.e. $\log g$, T_e, and M_{bol}) derived by us from the relation

$$\log Q = -6.454 + 0.5 \log g + \log P + 0.1 M_{bol} + \log T_e,$$

the value of the pulsation constant Q is derived to be $0^d.037$ which indicates that the period $0^d.1558$ is fundamental. Likewise, from the period $0^d.1188$, the value of Q is derived to be $0^d.028$ which differs from the theoretical value of $0^d.0252$ derived from model calculations for the first overtone δ Scuti pulsators (Petersen, 1976). The difference may be due to the uncertainty in the determination of $\log g$ because a change of ± 0.1 in $\log g$ corresponds to a change of $\pm 0^d.003$ in the value of Q.

Thus, it appears that the star HR 1225 pulsates in the fundamental mode with the period (P_0) of $0^d.1558$ as well as in the first overtone mode with the period (P_1) of $0^d.1188$. However, in periodogram analysis, the amplitude of light variation is found larger for the first overtone than the amplitude of the fundamental mode. This indicates that the first overtone mode is more prominent in the pulsation of the δ Scuti star HR 1225. Further, the period ratio (P_1/P_0) is derived to be 0.762, which is in fair agreement with the theoretical value of 0.757 for the δ Scuti stars pulsating in the radial modes (Petersen, 1976).

By use of the empirical relation (Petersen and Jorgensen, 1972)

$$\log \frac{M}{M_\odot} = 12.502 + \log g - 0.4\, M_{bol} - 4 \log T_e,$$

the mass of the star HR 1225 is derived to be 1.9 M which is in fair agreement with the value 2.0 $M_\odot$ derived from Iben's (1967) evolutionary tracks for the stars in the hydrogen shell burning stage of evolution.

Acknowledgement

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