PERIODOGRAM ANALYSIS OF THE LIGHT CURVES OF 44 TAU

S. K. Gupta

Uttar Pradesh State Observatory, Manora Peak Naini Tal 263 129
(Received October 12, 1977, revised January 9, 1979)

Abstract

The periodogram analysis of the light curves of the δ Scuti star 44 Tau (=HR 1287) has been carried out. The fundamental period of 44 Tau, based on the epochs of maxima, is found to be $0.^{d}144969$ and the beat period is found to be $0.^{d}43957$. The ratio of period for this star is $P_1/P_0 = 0.752$. The colour (B-V) and the position of the star on the HR-diagram suggest its spectral class to be F0 IV—F1 IV. The effective temperature of the star is derived to be nearly 7400 °K and its mass $2.0M_{\odot}$.

1. INTRODUCTION

The star 44 Tau [Sp : dF3; $V = 5.^{m}40$] was first reported as a δ Scuti variable by Danziger and Dickens (1967) who estimated for it a period of light variation of $0.^{d}132$ and also suggested a beat phenomenon in the light variations. On the basis of the least square residuals of (O-C) based on the maxima observed by Desikachary in 1967 and earlier by Danziger and Dickens (1967), the former (1973) deduced a fundamental period of $0.^{d}12655$ Alongside, he also obtained another fundamental period of $0.^{d}144948$ based on a periodogram analysis of his own observations. Percy and McAlary (1974) also obtained a fundamental period of $0.^{d}1449$. In order to study the light variation and the mode of pulsation in greater detail, we put the star on our observing program and we present herein the light and colour curves of the star as also some of its physical parameters.

2. OBSERVATIONS

The star was observed on 10 nights between 24 October through 17 December 1976 on the 38-cm. Cassegrain reflector of the Uttar Pradesh State Observatory using a cooled 1P21 photomultiplier tube and UBV filters of the Johnson and Morgan system. The star 42 Tau was used as a comparison star. The magnitudes were corrected for extinction using nightly extinction coefficients. The standard deviation of the observed magnitudes of the comparison star in V filter is $\pm 0.^{m}008$.

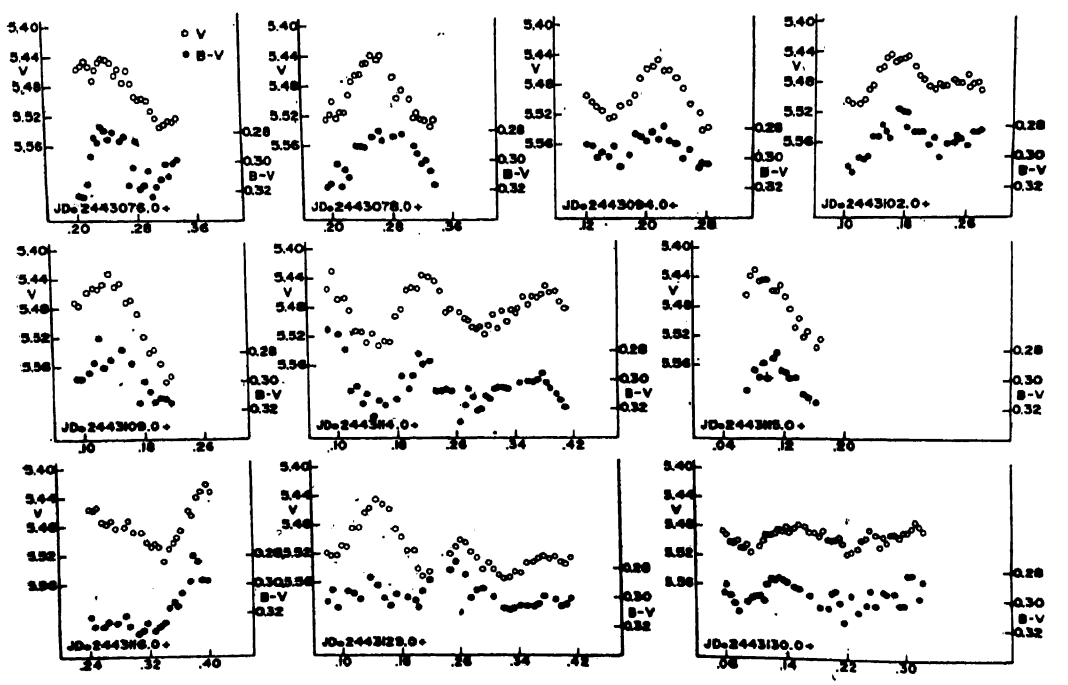

Fig. 1: Light and colour curves for 44 Tau.

Table 1

JD (Hel)	V	B-V	JD (Hel)	V	B-V
2443076.203	5.455	0.323	2443102.151	5.460	0.278
.208	.451	.324	.156	.448	.282
.213	.445	.315	.161	.444	.287
.218	.452	.296	.167	.454	.257
.223	.471	.284	.172	.450	.267
.227	.456	.287	.178	.449	.269
.232	.446	.276	.184	.446	.280
.237	.442	.274	.193	.460	.284
.242	.443	.285	.199	.472	.283
.247	.447	.280	.205	.478	.283
.252	.464	.266	.212	.486	.292
.257	.456	.286	.219	.490	.287
.263	.474	.283	.225	.482	.296
.268	.458	.318	.230	.486	.301
.274	.475	.304	.237	.485	.291
.278	.493	.286	.244	.478	.290
.283	.497	.319	.247	.481	.285
.288	.495	.316	.254	.482	.288
.294	.498	.306	.261	.471	.292
.299	.512	.324	.264	.488	.279
.305	.522	.317	.269	.483	.282
.311	.534	.312	.275	.481	.285
.317	.530	.302	2443102.279	.492	.282
.322	.525	.310	3109.091	.471	.298
.328	.527	.301	.096	.476	.298
2443076.333	.522	.299	.107	.458	.294
3078.192	.524	.318	.114	.452	.287
.197	.518	.316	.121	.454	.270
.202	.500	.326	.128	.447	.290
.207	.523	.302	.136	.432	.285
.212	.517	.318	.144	.450	.277
.217	.515	.306	.151	.445	.278
.223	.491	.292	.158	.471	.258
.228	.473	.266	·165	.469	.287
.233	.465	.290	.173	.487	.315
.238	.464	.290	.181	.519	.300
.243	.450	.291	.188	.540	.307
.248	.449	.274	.195	.536	.314
.253	.439	.284	.203	.556	.311
.261	.445	.280	.210	.581	.312
.266	.439	.286	.217	.573	.315
.282	.468	.284	3114.089	.454	.265
.287	.496	.263	.096	.430	.314
.293	.485	.282	.103	.469	.267
.305	.497	.328	.111	.467	.279
.310	.522	.290	.118	.484	.301
.314	.516	.295	.126	.512	.304
.320	.522	.302	.133	.514	.316
.325	.526	.300	.140	.528	.309
.332	.534	·307	.148	.516	.325
2443078.336	.525	.317	.156	.532	.304
3094.121	.495	.290	.164	.526	.307
.129	.502	.291	.171	.527	.288
.135	.510	.299	.179	.492	.313
.142	.515	.295	.186	.482	.297
.151	.525	.298	.195	.455	.306
.159	.523	.292	.202	.452	.297
.166	.509	.305	.210	.454	.282
.178	.505	.297	.217	.436	.289
.186	.495	.283	.225	.438	.287
.193	.472	.285	.253	.444	.308
.201	.461	.288	·240	.458	.308
.209	.456	.282	.247	.487	.307
.216	.448	.287	.254	.482	.308
.224	.461	.278	.266	.487	.329
.231	.462	.288	.273	.495	.317
.240	.472	.290	.278	.498	·306
.248	.486	.300	.284	.507	.312
.258	.507	.294	.289	.509	.321
.271	.519	.306	.294	.507	.320
.274	.542	.303	.300	.517	.311
2443094.282	.539	.304	.305	.503	.313
2443102.104	.504	.306	.311	.490	.306
.110	.508	.310	.317	.509	.305
.120	.508	.300	.324	.485	.305
.126	.503	.301	.330	.499	.306
.132	.490	.299	.335	.483	.322
.138	.484	.286	.341	.488	.314
2443102.145	5.463	0.286	2443114.347	5.481	0.302

Table 1 (Contd.)

JD (Hel)	V	B-V	JD (Hel)	V	B-V
2443114.353	5.467	0.313	2443129.219	5.544	0.285
.359	.476	.301	.247	.520	.281
.365	.465	.302	.255	.510	.275
.372	.467	.300	.262	.500	.297
.378	.462	.295	.269	.504	.284
.383	.451	.302	.276	.517	.300
.388	.459	.306	.284	·525	.295
.398	.458	.310	.291	.541	.293
.403	.472	.314	.299	.532	.319
2443114.409	.481	.318	.306	.541	.300
3115.071	.463	.307	.313	.549	.317
.076	.438	.324	.320	.554	.308
.082	.429	.293	.328	.552	.308
.088	.445	.298	.335	.544	.308
.093	.443	.288	.344	.546	.306
.098	.443	.299	.352	.532	.306
.105	.458	.285	.361	.531	.307
			.368	.526	.305
.110	.459	.281	.375	.523	.299
.116	.451	.294	.383	.525	.315
.121	.466	.295	.392	.523	.301
.127	.483	.299	.399	.531	.306
.134	.509	.298	.405	.538	.305
.139	.496	.323	2443129.412	.524	.301
.145	.521	.310	3130.057	.487	.296
.150	.514	.312	.061	.492	.290
.162	.536	.315	.066	.502	.298
2443115.168	.524	.328	.070	.504	.303
3116.241	.456	.322	.076	.500	.309
.247	.457	.329	.080	.509	.294
.252	.454	.339	.084	.511	.291
.259	.473	329.	.088	.506	.302
.264	.477	.326	.093	.517	.299
.270	.472	.342	.100	.473	.298
.276	.482	.327	.105	.508	.298
.282	.465	.340	.110	.500	.301
.288	.481	.321	.113	.492	.290
.293	.471	.329	.119	.492	.286
.300	.488	.317	.124	.490	.287
.306	.476	.334	.129	.484	.285
.311	.487	.322	.135	.487	.287
.317	.501	.326	.140	.481	.288
.323	.509	.318	.144	.489	.304
.328	.504	.332	.150	.483	.292
.334	.508	.329	.156	.478	.309
.340	.528	.327	.165	.481	.293
.347	.511	.316	.170	.489	.298
.354	.503	.312	.177	.489	.308
.357	.495	.315	.184	.494	.306
.364	.486	.306	.189	.486	.323
.375	.459	.298	.195	.489	.307
.379	.463	.280	.200	.500	.296
.386	.440	.285	.206	.499	.295
391.	.431	.298	.211	.496	.303
.398	.421	.298	.216	.504	.316
2443116.403	.432	.283	.221	.518	.296
3129.080	.519	.303	.227	.516	.298
.087	.522	.295	.237	.511	.309
.094	.522	.308	.242	.499	.304
.101	.508	.311	.248	.497	.304
.108	.510	.296	.253	.484	.294
.116	.484	.298	.261	.492	.304
.124	.483	.302	.266	.508	.279
.132	.463	.305	.271	.494	.294
.139	.458	.286	.277	.501	.296
.148	.444	.292	.282	.491	.314
.156	.451	.301	.287	.491	.296
.165	.458	.306	.293	.495	.304
.173	.485	.298	.299	.488	.305
.181	.496	.293	.304	.488	.283
.189	.515	.300	.310	.482	.283
.199	.515	.302	.315	.473	.305
.204	·540	.307	.320	.479	.299
2443129.210	5·550	0.296	2443130·325	5.485	0 288

Table 2

Epochs of Maxima	O—C
2439792.398	.0000
39796.358	+.0458
39798.340	—.0017
39800.226	—.0003
39806.190	+.0199
39837.171	—.0224
39856.183	—.0014
39857.206	+.0069
40513.916	+.0073
40880.535	—.0003
40881.541	—.0091
40887.789	+.0052
41977.656	—.0047
41977.787	—.0187
42027.668	—.0070
43076.227	—.0088
43078.256	—.0094
43094.216	+.0041
43102.172	—.0132
43114.218	+.0003
43115.095	+.0075
43129.149	—.0005
43130.154	—.0103

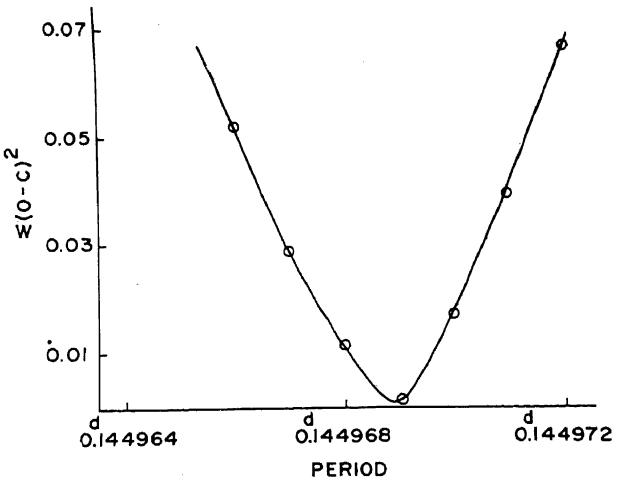

Fig. 2: A plot between primary period versus Σ (O-C)^2 for 44 Tau.

The light curves of 44 Tau (Fig.1) on different nights show a variable amplitude ranging from $0^m.03$ to $0^m.10$. The light variation is not strictly sinusoidal on all of the nights. On two of the nights, two full cycles could be covered. All the observations listed in table 1 were reduced to the standard UBV system.

3. PERIOD

A preliminary mean period of $0^d.145$ was obtained using our own observations of 10 epochs of maxima. Combining these with the epochs of maxima by Percy (1973), Desikachary (1973) and Percy and McAlary (1974) as tabulated in table 2 (the total observations thus being spread over nine years) and by plotting Σ (O-C)^2 versus period as shown in Fig. 2, we estimate the period to be $0^d.144969 \pm 0^d.000001$ corresponding to zero epoch of $JD_\odot 2439792.398$. This period is consistent with the values of the period obtained earlier by Desikachary (1973) and by Percy and McAlary (1974). Using the method of Wehlau and Leung (1964), a periodogram analysis has been carried out for these observations, and the highest peak is found to correspond to the frequency 6.898 ± 0.001 cycles/day (Fig.3) which corresponds to a period $0^d.1450$ which agrees with the period deduced above. After subtracting the contribution due to this period from the observed data and by plotting Σ (C-O)^2 versus period for the residuals, as shown in Fig. 4, a secondary period of $0^d.109016 \pm 0^d.000001$ is found to exist which, in the periodogram analysis for residuals, corresponds to the peak at the frequency 9.173 ± 0.001 cycles/day (Fig. 5). From these periods, the beat period is estimated to be $0^d.43957$. Assuming the primary period as fundamental (P_0) and the secondary period as the first overtone (P_1), we find the period ratio $P_1/P_0 = 0.752$, which is in closer agreement to the thoretical value of 0.75 for radial mode pulsations, than the value of 0.72 given by Percy and McAlary (1974). Thus the hypothesis that the pulsations in δ Scuti stars are due to radial mode is supported

4. DISCUSSION

The (B-V) colour of the star varies in phase with the V magnitude as shown in Fig. 1. The mean values of (B-V) and (U-B) are found to be $0^m.30 \pm 0^m.01$ and $0^m.11 \pm 0^m.01$ respectively, the average variation in the amplitude of (B-V) during a beat period being $\backsimeq 0^m.03$. The value of (B-V) found by us is lower than the previous value of $0^m.34$ determined by Danziger and Dickens (1967). On the basis of this value of (B-V), the spectral class of this star should be F_0 or F_1 (vide Allen, 1973). The star has earlier been variously assigned a spectral class of dF_3 (Danziger and Dickens, 1967), and F_2 IV (Baglin et al. 1973).

Using (B-V) — (b-y) calibration (Golay, 1972) and T_e – (b-y) calibration (Breger, 1975), the effective temperature of the star is found to be nearly 7400°K which is in good agreement with a similar value determined by Joshi and Rautela (1976).

The absolute magnitude of $1^m.20 \pm 0^m.22$ derived from the P-L-C relation (Breger and Bregman, 1975) s in agreement with the value of $1^m.30$ determined from uvby β calibration by Dickens and Penny (1971). On the assumption that the δ Scuti stars are in the post main sequence phase of evolution (Eggen, 1956) the bolometric correction for this star is taken to be $-0^m.26$ (Allen, 1973), whence the bolometric magnitude is derived to be $1^m.14 \pm 0^m.22$m. This compares well with the value of $1^m.0$ derived from theoretical P-L-C relation for δ Scuti stars pulsating in the fundamental

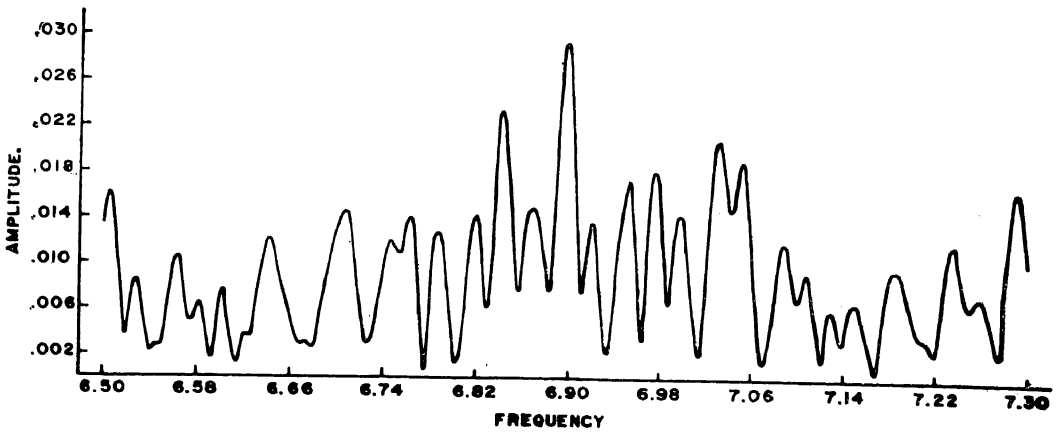

Fig. 3: Periodogram analysis for 44 Tau using observations in V.

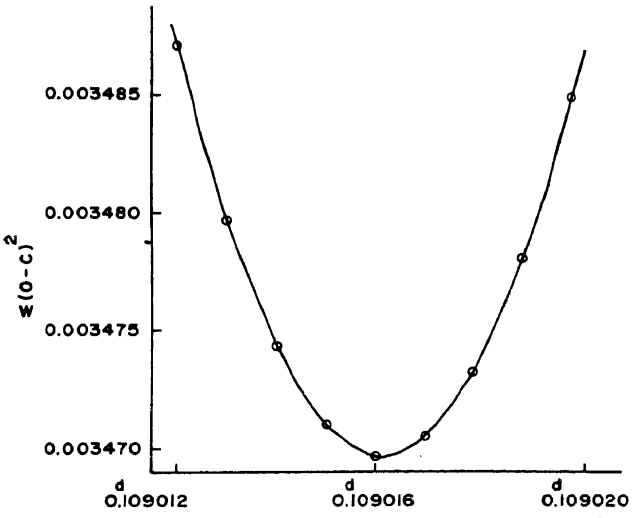

Fig. 4: A plot between secondary period versus $\Sigma (O-C)^2$ for 44 Tau.

mode, based on linear non-adiabatic model calculations given by Tsvetkov (1977).

Further, from the relation given by Breger and Bregman (1975), the pulsation constant Q is derived to be $0^d.039 \pm {}^0{}^d.003$ which indicates that the primary period is fundamental. The relation $Q = \rho\sqrt{e/e_o}$ further yields the value of $e/e_o = 0.072$.

The mass of this star, determined from the mass-luminosity relation derived by Tsvetkov (1977) based on Iben's (1967) evolutionary tracks for the stars in the hydrogen shell burning stage, is 2.0 $M_\odot$ while that from the relation given by Dickens and Penny (1971), is found to be 2.1 $M_\odot$. These estimates are internally consistent and are in good agreement with the value 2.0 $M_\odot$ determined by Joshi and Rautela (1976). From the value of

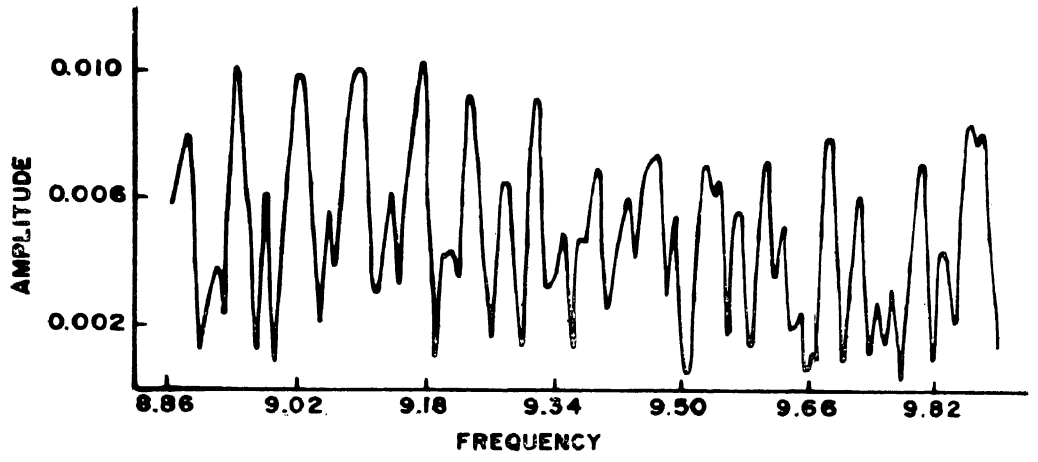

Fig. 5: Periodogram analysis of the residuals for 44 Tau after subtraction of the peak at 6.898 c/d.

mass and density determined by us, the radius of the star is found to be 1.9 $R_\odot$ while Joshi and Rautela (1976) estimated its radius to be 2.3 $R_\odot$. However, considering that the error in the latter determination could be up to $\pm$ 25% (verbal communication by the authors) the value derived by us appears to be more reliable than the previous estimates. The position of the star on the H-R diagram indicates that it belongs to luminosity class IV and that the star is in the hydrogen shell burning phase.

ACKNOWLEDGEMENT

The author wishes to express his thanks to Dr. S.D. Sinvhal for suggestions and for helpful discussions. The author is also thankful to the referees for their valuable comments.

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