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STRÖMGREN PHOTOMETRY OF THE HIGH AMPLITUDE δ SCUTI STAR HD 79889

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RESUMEN

Se ha realizado fotometría fotoeléctrica *uvbyβ* de la estrella δ Scuti de gran amplitud HD 79889. El análisis de los datos, mediante el método de la Transformada de Fourier, indica que HD 79889 es un pulsador monoperiódico. Mediante el método clásico O–C se obtiene un período de pulsación de 0.095869448 días. Se han determinado los parármetros físicos de esta estrella.

ABSTRACT

uvbyβ photoelectric photometry of the high amplitude δ Scuti type star HD 79889 is presented. Analysis of the data using the Fourier Transform establishes HD 79889 as a monoperiodic pulsator. Using the classical O–C method, a period of 0.095869448 days is obtained. The physical parameters of this star are determined.

Key words: **PHOTOMETRY – STARS-δ SCUTI – STARS-PULSATION**

I. INTRODUCTION

HD 79889 was first reported as a variable star by 'ja (1987), who estimated a period of 0.0958697^d ith a V amplitude of 0.4^m, with eight nights of bservation, establishing it as a member of the high mplitude δ Scuti star class. From the epochs of ıe light maxima obtained during his observational :ason, he derived the following ephemeris:

$$\text{light maxima} = \text{JD(hel)}2446506.0074 + 0.0958697\ E$$

We carried out observations in the Strömgren /stem to determine the physical parameters of this :ar.

II. OBSERVATIONS

The observations were carried out in the years 987, 1988 and 1989 at Sierra Nevada Observatory ı Spain, over five nights using the 75-cm telescope ith simultaneous photometric observations with ıe *uvby* filters of the Strömgren system, and three ther nights using the 60-cm telescope, with the filter only. Moreover, a night was devoted to multaneously measuring HD 79889 in the n and bands in the Hβ Crawford system using the 75- n telescope. The photometer attached to the 60-cm telescope is a single channel pulse-counting one using a cooled Lallemand photomultiplier (Sareyan 1978). The other photometer is a six-channel one, containing both *uvby* and Hβ sections, using uncooled EMI photomultipliers type 9789 QA. The *uvby* instrument is a four-channel spectrograph-photometer and the Hβ photometer is a two-channel one (Gronbech, Olsen and Strömgren 1976; Gronbech and Olsen 1977).

The comparison stars were the same stars used by Oja (1987). C1 = HD 79763 and C2 = HD 80079, whose spectral types are A0 in both cases (*SAO Star Catalogue* 1971) which is close to the A3 reported in the same catalogue for HD 79889. Each integration generally consists of 60 s for the variable and 40 s for each of the two comparison stars. This gives us for any of the stars an internal observational error of less than 0.005^m for the u filter. In the Hβ system, each observation consisted of three integrations of 35 s, which yielded an internal error better than 0.006^m in the n band.

More than 150 observations were obtained for each comparison star during the five nights using the 75-cm telescope. The mean errors from night to night for C2–C1 were 0.004^m, 0.002^m, 0.002^m, and 0.002^m for y, b–y, m_1 and c_1, in the instrumental system. There is no sign of variability for either

C1 or C2 during the observations reported here, according to Oja (1987), and this also shows the uniformity of the system. The mean error obtained for C2–C1 from the observations using the 60-cm telescope is $\Delta y = 0.003^m$, very similar to that obtained using the 75-cm telescope.

To take into account the range in color indices of the objects in the present study, a set of 25 standard stars were carefully selected from the lists of Crawford and Mander (1966); Crawford and Barnes (1970) as well as by Olsen (1983), although these standard stars are slightly brighther than the studied stars. Six of these standards were utilized for extinction procedures and at least three measurements of each were made every night before, at and after the meridian; moreover, one night was devoted exclusively to observations of standard stars.

We took care to be able to carefully transform our data into the $uvby\beta$ system of Olsen (1983), which is essentially that of Crawford and Mander (1966) and Crawford and Barnes (1970). In this way, the typical deviations obtained in the transformations to the standard system were: 0.010^m, 0.007^m, 0.008^m, 0.010^m and 0.006^m for V, b–y, m_1, c_1 and β respectively. The following values were obtained for HD 79763: $V = 5.964^m$ (±0.005), b–$y = 0.024^m$ (±0.003), $m_1 = 0.174^m(\pm0.003)$ and $c_1 = 1.026^m$ (±0.004); for HD 80079: $V = 6.915^m(\pm0.007)$, b–$y = -0.012^m(\pm0.003)$,$m_1 = 0.138^m$ (±0.004) and $c_1 = 1.074^m(\pm0.005)$. All the *uvby* data obtained using the 75-cm telescope are presented in Table 1, as magnitude differences of HD 79889–HD 79763 in the standard system versus heliocentric Julian Day. In Table 2 the Hβ values for the variable star are listed. By using the single-channel photometer we collected only observations in the y filter for the variable and the two comparison stars, but knowing $\Delta(b$–$y)$ in the standard system and Δy in the instrumental system for the star minus C1, we can also calculated ΔV in the standard system for these stars. The magnitude differences calculated in this way are presented in Table 3.

III. RESULTS AND DISCUSSION

Although the light curves for HD 79889 from Oja (1987) did not indicate changes in light variation, we have tested this phenomenon using the Fourier Transform method (López de Coca, Garrido and Rolland 1984) obtaining on the periodogram a principal peak very close to that frequency which corresponds to the period given by Oja. After prewhitenning this frequency, the resulting periodogram did not show any trace of another peak, suggesting the monoperiodicity of this star. This analysis was done for all of the four *uvby* filters, and the results, in all four cases, were consistent.

If HD 79889 is a monoperiodic star, the classic O–C method can be applied. It is well know that for one star with the characteristics of H 79889, a high amplitude star, and with the s of data collected by both Oja and by us (Sier Nevada Observatory, SN). The precision that ca be obtained using the O–C method is much larg than that derived using the Fourier Transfor method. In this way, the times of maxima fro the observations collected by both Oja (1987) (O8' and SN were calculated and they are listed in th second column of Table 4. In total, nineteen lig maxima times (from 1986 to 1989) were used for th determination of the ephemeris of the light curve HD 79889.

There are some problems related to the der vation of these times of maxima because the lig curve is not symmetric. In relation to this point, is very important to make a great effort, not on to derive these times of maxima homogeneousl but also with precision; that is, the time of maxim calculated must correspond to the instant th maximum light occurs in order to avoid systemat tendencies. Now, the precision is difficult evaluate in this case, but simultaneous photometr can be useful because we can compare the resul obtained using each one of the four filters.

We have made comparisons with different bise tional methods that take into account the asym metry of the light curve, but the results of thes methods depend too much on the observed poin that define the maximum light and these points pr sent two problems: first, generally the number points around maximum is not large, and secon the observed points are not always very well def ned. This implies that these methods in some ca ses do not give homogeneous results for such analy sis. A second possibility is to adjust a polynomi to the points around the maximum. This metho also presents some problems: if the order of the fi ting is very low, tendencies appear in the result also, if the order is very high there is a great de pendence with isolated points and the method do not give homogeneous results. Moreover, it is di ficult to find the best order that joins these par meters. A third possibility consists in an adjustme using Fourier series. This method gives homog neous and precise results, especially when the num ber of points is large and the light curves are we defined, but there is also some difficulty in applyin it to isolated maxima of light if the number of obse ved points is not large and the precision is not hig We have inspected a fourth method based on cu bic spline routines that takes into account a certai degree of randomness for the observational poin and rejects those points that are separated a certai distance from the general tendency. We can test

TABLE 1

MAGNITUDE DIFFERENCES HD 79889–HD 79763

HJD	Δu	Δv	Δb	ΔV	Δ(b-y)	Δm_1	Δc_1
2446950. +							
0.3744	2.905	2.903	2.805	2.703	0.102	-0.004	-0.096
0.3789	2.959	2.976	2.875	2.759	0.116	-0.016	-0.118
0.3828	2.992	3.012	2.903	2.772	0.131	-0.021	-0.130
0.3865	3.023	3.050	2.936	2.800	0.135	-0.021	-0.142
0.3921	3.064	3.115	2.994	2.841	0.153	-0.031	-0.172
0.3961	3.090	3.155	3.025	2.878	0.148	-0.018	-0.194
0.4002	3.113	3.195	3.060	2.905	0.155	-0.019	-0.218
0.4045	3.134	3.231	3.091	2.930	0.161	-0.021	-0.236
0.4085	3.153	3.259	3.112	2.951	0.161	-0.014	-0.254
0.4126	3.182	3.281	3.138	2.965	0.173	-0.031	-0.242
0.4180	3.199	3.303	3.153	2.980	0.173	-0.023	-0.254
0.4224	3.203	3.314	3.168	2.992	0.176	-0.030	-0.258
0.4264	3.208	3.321	3.178	2.997	0.181	-0.038	-0.256
0.4314	3.197	3.315	3.168	3.003	0.165	-0.017	-0.266
0.4354	3.162	3.277	3.143	2.975	0.168	-0.034	-0.249
0.4393	3.114	3.229	3.090	2.929	0.161	-0.022	-0.254
0.4445	3.018	3.114	2.988	2.851	0.138	-0.012	-0.223
0.4480	2.938	3.011	2.904	2.777	0.127	-0.020	-0.180
0.4517	2.848	2.882	2.786	2.675	0.110	-0.014	-0.131
0.4567	2.796	2.788	2.707	2.619	0.088	-0.007	-0.074
0.4611	2.822	2.783	2.696	2.601	0.095	-0.008	-0.049
0.4650	2.840	2.820	2.737	2.636	0.101	-0.019	-0.063
2446951. +							
0.3698	3.159	3.271	3.127	2.970	0.157	-0.013	-0.256
0.3743	3.188	3.300	3.149	2.990	0.159	-0.008	-0.262
0.3778	3.199	3.310	3.170	2.996	0.174	-0.034	-0.250
0.3827	3.210	3.325	3.178	3.005	0.171	-0.027	-0.261
0.3870	3.205	3.325	3.181	3.009	0.172	-0.029	-0.264
0.3911	3.178	3.300	3.158	3.002	0.156	-0.014	-0.264
0.3957	3.139	3.260	3.124	2.977	0.147	-0.011	-0.256
0.3997	3.078	3.211	3.071	2.934	0.137	0.003	-0.273
0.4036	2.994	3.106	2.988	2.859	0.129	-0.010	-0.231
0.4084	2.892	2.956	2.854	2.751	0.102	0.000	-0.166
0.4129	2.805	2.816	2.728	2.645	0.083	0.006	-0.100
0.4168	2.770	2.760	2.684	2.604	0.081	-0.005	-0.065
0.4216	2.805	2.793	2.708	2.626	0.082	0.002	-0.073
0.4255	2.850	2.837	2.747	2.663	0.084	0.006	-0.077
0.4318	2.905	2.917	2.824	2.720	0.104	-0.011	-0.105
0.4382	2.969	3.006	2.896	2.776	0.120	-0.010	-0.146
0.4427	2.997	3.061	2.944	2.820	0.124	-0.006	-0.181
0.4463	3.042	3.101	2.985	2.847	0.138	-0.022	-0.174
0.4512	3.063	3.147	3.019	2.882	0.138	-0.011	-0.211
0.4549	3.097	3.184	3.050	2.913	0.137	-0.003	-0.222
0.4595	3.133	3.211	3.080	2.935	0.145	-0.014	-0.209
2447121. +							
0.6163	3.069	3.135	3.009	2.868	0.140	-0.014	-0.194
0.6193	3.089	3.165	3.033	2.887	0.147	-0.015	-0.208
0.6219	3.111	3.186	3.056	2.898	0.158	-0.029	-0.205
0.6246	3.129	3.206	3.066	2.921	0.145	-0.005	-0.217
0.6283	3.142	3.237	3.097	2.933	0.165	-0.025	-0.236
0.6310	3.161	3.261	3.111	2.953	0.158	-0.009	-0.249
0.6338	3.170	3.270	3.127	2.954	0.173	-0.030	-0.243
0.6368	3.179	3.287	3.140	2.971	0.169	-0.021	-0.256
0.6394	3.178	3.300	3.150	2.981	0.170	-0.020	-0.271
0.6423	3.198	3.306	3.164	2.990	0.174	-0.031	-0.251
0.6478	3.201	3.319	3.173	3.000	0.173	-0.027	-0.265
0.6507	3.197	3.315	3.168	2.997	0.171	-0.024	-0.265
0.6534	3.192	3.316	3.164	3.005	0.159	-0.007	-0.277
0.6563	3.166	3.299	3.152	2.986	0.167	-0.020	-0.279
0.6590	3.148	3.270	3.130	2.973	0.157	-0.018	-0.261
0.6619	3.118	3.234	3.100	2.949	0.150	-0.017	-0.249
0.6646	3.069	3.188	3.054	2.908	0.147	-0.013	-0.254
0.6675	3.013	3.117	2.988	2.858	0.130	-0.001	-0.234
0.6730	2.889	2.941	2.839	2.740	0.099	0.003	-0.154
0.6759	2.837	2.849	2.760	2.667	0.093	-0.004	-0.100
0.6793	2.800	2.787	2.707	2.622	0.085	-0.006	-0.066
0.6820	2.798	2.780	2.702	2.618	0.083	-0.005	-0.059
0.6849	2.822	2.795	2.717	2.636	0.081	-0.003	-0.051
0.6878	2.850	2.828	2.748	2.650	0.098	-0.017	-0.059
0.6912	2.893	2.877	2.785	2.691	0.094	-0.002	-0.076
0.6942	2.920	2.918	2.820	2.715	0.104	-0.005	-0.098
0.6968	2.946	2.954	2.853	2.745	0.108	-0.006	-0.109
2447551. +							
0.4004	3.094	3.155	3.019	2.879	0.140	-0.004	-0.197
0.4048	3.128	3.190	3.058	2.906	0.151	-0.019	-0.194
0.4079	3.140	3.214	3.079	2.921	0.158	-0.023	-0.209
0.4119	3.154	3.246	3.102	2.945	0.157	-0.013	-0.236
0.4154	3.163	3.268	3.124	2.963	0.160	-0.016	-0.250
0.4196	3.183	3.291	3.149	2.979	0.170	-0.028	-0.250
0.4230	3.198	3.305	3.158	2.988	0.169	-0.022	-0.256
0.4273	3.208	3.321	3.175	3.004	0.172	-0.026	-0.260
0.4312	3.205	3.323	3.178	3.009	0.169	-0.025	-0.262
0.4389	3.173	3.302	3.162	2.998	0.164	-0.024	-0.269
0.4429	3.133	3.260	3.129	2.973	0.156	-0.024	-0.259
0.4482	3.061	3.169	3.047	2.906	0.141	-0.019	-0.230
0.4520	2.988	3.077	2.962	2.835	0.127	-0.013	-0.204
0.4552	2.913	2.980	2.870	2.761	0.109	0.001	-0.178
0.4587	2.836	2.861	2.768	2.678	0.089	0.005	-0.119
0.4626	2.793	2.789	2.706	2.624	0.083	-0.001	-0.078
0.4663	2.797	2.785	2.701	2.622	0.080	0.004	-0.072

TABLE 1 (CONTINUED)

HJD	Δu	Δv	Δb	ΔV	$\Delta(b-y)$	Δm_1	Δc_1
2447551. +							
0.4692	2.816	2.810	2.722	2.640	0.082	0.005	-0.081
0.4723	2.853	2.849	2.758	2.666	0.092	-0.002	-0.086
0.4759	2.898	2.895	2.801	2.700	0.101	-0.007	-0.092
0.4795	2.933	2.936	2.842	2.730	0.112	-0.017	-0.098
0.4826	2.957	2.981	2.877	2.763	0.114	-0.010	-0.128
0.4869	2.992	3.043	2.925	2.802	0.123	-0.005	-0.170
0.4900	3.022	3.072	2.957	2.825	0.132	-0.018	-0.165
0.4930	3.043	3.107	2.988	2.848	0.140	-0.021	-0.184
0.4969	3.075	3.148	3.021	2.876	0.145	-0.019	-0.199
0.4998	3.096	3.174	3.044	2.894	0.150	-0.021	-0.208
0.5030	3.118	3.204	3.067	2.918	0.149	-0.012	-0.222
0.5067	3.145	3.238	3.099	2.939	0.160	-0.022	-0.232
0.5099	3.158	3.256	3.119	2.955	0.164	-0.026	-0.236
0.5128	3.173	3.268	3.128	2.969	0.159	-0.019	-0.234
0.5159	3.187	3.292	3.148	2.986	0.162	-0.017	-0.250
0.5197	3.197	3.312	3.162	2.996	0.166	-0.016	-0.265
0.5228	3.212	3.322	3.173	3.005	0.168	-0.020	-0.258
0.5266	3.220	3.320	3.177	3.009	0.168	-0.024	-0.244
0.5300	3.198	3.317	3.172	3.006	0.166	-0.020	-0.264
0.5337	3.190	3.308	3.166	3.002	0.164	-0.023	-0.259
0.5380	3.152	3.274	3.136	2.976	0.160	-0.022	-0.260
0.5431	3.078	3.190	3.067	2.925	0.142	-0.019	-0.235
0.5508	2.914	2.984	2.878	2.766	0.112	-0.006	-0.176
0.5546	2.841	2.857	2.764	2.679	0.085	0.008	-0.108
0.5583	2.800	2.784	2.702	2.624	0.078	0.003	-0.066
0.5627	2.815	2.785	2.708	2.625	0.082	-0.005	-0.048
0.5674	2.864	2.842	2.748	2.661	0.087	0.008	-0.073
0.5712	2.896	2.890	2.794	2.688	0.106	-0.009	-0.090
0.5760	2.954	2.960	2.856	2.744	0.112	-0.008	-0.109
0.5798	2.983	3.009	2.901	2.781	0.120	-0.012	-0.134
0.5834	3.022	3.051	2.941	2.810	0.131	-0.020	-0.139
0.5871	3.059	3.100	2.980	2.841	0.140	-0.020	-0.160
0.5912	3.080	3.141	3.011	2.867	0.144	-0.015	-0.190
0.5946	3.105	3.172	3.042	2.892	0.150	-0.020	-0.198
0.5987	3.139	3.205	3.073	2.912	0.161	-0.029	-0.198
0.6022	3.148	3.236	3.097	2.938	0.159	-0.021	-0.226
0.6061	3.170	3.264	3.117	2.952	0.165	-0.018	-0.241
0.6096	3.194	3.284	3.139	2.972	0.167	-0.022	-0.236
0.6139	3.208	3.307	3.160	2.989	0.170	-0.022	-0.246
0.6172	3.204	3.319	3.167	2.993	0.174	-0.022	-0.267
0.6211	3.220	3.319	3.174	3.004	0.170	-0.026	-0.244
0.6243	3.215	3.324	3.174	3.004	0.170	-0.020	-0.259
0.6277	3.194	3.318	3.170	3.004	0.166	-0.017	-0.273
0.6314	3.186	3.299	3.154	2.991	0.163	-0.018	-0.257
0.6350	3.147	3.260	3.125	2.967	0.158	-0.024	-0.248
0.6385	3.093	3.210	3.072	2.930	0.142	-0.005	-0.254
0.6417	3.032	3.132	3.009	2.875	0.134	-0.012	-0.222

HJD	Δu	Δv	Δb	ΔV	$\Delta(b-y)$	Δm_1	Δc_1
2447551. +							
0.6457	2.955	3.021	2.905	2.793	0.112	0.004	-0.181
0.6491	2.873	2.906	2.808	2.711	0.097	0.002	-0.132
0.6523	2.823	2.821	2.733	2.648	0.085	0.002	-0.085
0.6556	2.806	2.781	2.704	2.621	0.083	-0.006	-0.053
0.6589	2.815	2.794	2.717	2.630	0.087	-0.011	-0.055
0.6625	2.860	2.838	2.750	2.660	0.089	-0.001	-0.066
0.6657	2.901	2.877	2.785	2.690	0.095	-0.003	-0.068
0.6690	2.925	2.928	2.822	2.719	0.103	0.002	-0.108
0.6720	2.955	2.961	2.858	2.746	0.112	-0.010	-0.109
0.6770	2.998	3.028	2.916	2.790	0.125	-0.013	-0.142
0.6802	3.026	3.063	2.948	2.821	0.127	-0.012	-0.153
0.6835	3.057	3.100	2.983	2.842	0.141	-0.025	-0.159
0.6868	3.083	3.128	3.009	2.864	0.145	-0.026	-0.163
0.6905	3.096	3.168	3.042	2.890	0.151	-0.025	-0.199
0.6936	3.120	3.201	3.062	2.910	0.152	-0.012	-0.220
0.6971	3.143	3.225	3.083	2.929	0.154	-0.013	-0.223
0.7004	3.162	3.247	3.107	2.947	0.160	-0.019	-0.225
0.7045	3.171	3.273	3.128	2.957	0.170	-0.026	-0.246
0.7076	3.184	3.291	3.146	2.983	0.162	-0.017	-0.253
0.7108	3.186	3.302	3.158	2.988	0.170	-0.026	-0.260
0.7139	3.199	3.311	3.167	2.990	0.177	-0.034	-0.256
0.7177	3.218	3.323	3.173	3.004	0.168	-0.018	-0.256
0.7210	3.206	3.326	3.174	3.003	0.171	-0.018	-0.273
0.7244	3.185	3.319	3.165	3.003	0.162	-0.007	-0.289
0.7277	3.169	3.290	3.149	2.989	0.160	-0.018	-0.262
0.7318	3.120	3.248	3.107	2.954	0.153	-0.012	-0.270
0.7352	3.068	3.187	3.058	2.911	0.146	-0.017	-0.250
2447553. +							
0.5165	3.129	3.198	3.066	2.909	0.157	-0.025	-0.201
0.5200	3.154	3.227	3.093	2.935	0.158	-0.024	-0.207
0.5231	3.169	3.255	3.116	2.959	0.157	-0.017	-0.226
0.5261	3.184	3.274	3.134	2.969	0.166	-0.025	-0.228
0.5304	3.195	3.306	3.160	2.996	0.164	-0.017	-0.258
0.5345	3.202	3.315	3.167	3.005	0.162	-0.014	-0.261
0.5377	3.202	3.320	3.177	3.004	0.172	-0.029	-0.262
0.5412	3.195	3.321	3.171	3.001	0.170	-0.020	-0.276
0.5443	3.194	3.309	3.168	3.003	0.165	-0.024	-0.256
0.5478	3.186	3.308	3.163	3.000	0.163	-0.018	-0.267
0.5512	3.143	3.272	3.131	2.978	0.154	-0.014	-0.269
0.5548	3.102	3.220	3.090	2.938	0.152	-0.022	-0.247
0.5582	3.050	3.150	3.022	2.894	0.129	-0.002	-0.226
0.5618	2.968	3.053	2.939	2.817	0.122	-0.008	-0.198
0.5648	2.893	2.955	2.853	2.748	0.105	-0.004	-0.162
0.5679	2.827	2.854	2.757	2.665	0.092	0.004	-0.123
0.5709	2.785	2.789	2.705	2.622	0.083	0.001	-0.088
0.5739	2.787	2.777	2.696	2.616	0.079	0.002	-0.072

TABLE 1 (CONTINUED)

HJD 2447553. +	Δu	Δv	Δb	ΔV	Δ(b-y)	Δm_1	Δc_1
0.5777	2.816	2.799	2.719	2.638	0.082	-0.002	-0.062
0.5809	2.853	2.830	2.746	2.650	0.096	-0.012	-0.062
0.5841	2.892	2.888	2.794	2.700	0.094	0.000	-0.090
0.5870	2.925	2.918	2.821	2.720	0.102	-0.006	-0.088
0.5910	2.976	2.979	2.874	2.758	0.116	-0.012	-0.107
0.5946	3.009	3.029	2.920	2.797	0.124	-0.015	-0.128
0.5975	3.036	3.066	2.954	2.825	0.129	-0.016	-0.142
0.6009	3.049	3.0[illegible]	2.984	2.848	0.136	-0.022	-0.161
0.6043	3.066	3.132	3.011	2.872	0.139	-0.018	-0.187
0.6072	3.094	3.162	3.032	2.890	0.142	-0.013	-0.198
0.6103	3.116	3.180	3.054	2.902	0.152	-0.026	-0.190
0.6138	3.142	3.222	3.082	2.930	0.152	-0.013	-0.219
0.6175	3.142	3.245	3.099	2.942	0.158	-0.012	-0.248
0.6205	3.168	3.262	3.124	2.966	0.159	-0.021	-0.231
0.6234	3.177	3.272	3.130	2.966	0.164	-0.022	-0.237
0.6263	3.178	3.290	3.149	2.987	0.162	-0.022	-0.253
0.6297	3.203	3.309	3.167	2.999	0.168	-0.027	-0.247
0.6327	3.200	3.313	3.169	3.004	0.165	-0.021	-0.258
0.6356	3.202	3.317	3.171	3.003	0.168	-0.023	-0.259
0.6385	3.196	3.309	3.170	3.002	0.168	-0.030	-0.252
0.6420	3.186	3.310	3.164	2.999	0.165	-0.020	-0.269
0.6458	3.149	3.281	3.138	2.975	0.162	-0.019	-0.276

HJD 2447553. +	Δu	Δv	Δb	ΔV	Δ(b-y)	Δm_1	Δc_1
0.6485	3.130	3.260	3.118	2.966	0.151	-0.009	-0.272
0.6511	3.095	3.211	3.076	2.927	0.150	-0.016	-0.250
0.6539	3.042	3.150	3.017	2.882	0.136	-0.003	-0.241
0.6566	2.997	3.088	2.967	2.834	0.132	-0.012	-0.212
0.6601	2.910	2.972	2.862	2.750	0.112	-0.003	-0.172
0.6629	2.848	2.880	2.784	2.685	0.099	-0.003	-0.127
0.6657	2.804	2.809	2.728	2.632	0.096	-0.014	-0.086
0.6685	2.789	2.776	2.697	2.614	0.082	-0.003	-0.066
0.6718	2.807	2.784	2.707	2.619	0.088	-0.011	-0.054
0.6745	2.830	2.813	2.727	2.636	0.090	-0.004	-0.070
0.6774	2.860	2.850	2.761	2.665	0.096	-0.006	-0.079
0.6801	2.902	2.888	2.794	2.691	0.103	-0.008	-0.081
0.6828	2.924	2.922	2.824	2.711	0.113	-0.015	-0.097
0.6862	2.960	2.963	2.862	2.744	0.118	-0.018	-0.104
0.6891	2.985	3.011	2.903	2.778	0.124	-0.016	-0.134
0.6921	3.017	3.043	2.935	2.797	0.139	-0.031	-0.134
0.6950	3.034	3.072	2.958	2.823	0.135	-0.020	-0.152
0.6977	3.062	3.103	2.988	2.840	0.148	-0.033	-0.156
0.7039	3.094	3.168	3.040	2.893	0.148	-0.020	-0.201
0.7094	3.122	3.208	3.074	2.922	0.152	-0.018	-0.220
0.7127	3.131	3.222	3.088	2.926	0.161	-0.026	-0.226

TABLE 2

Hβ VALUES FOR HD 79889

HJD	β	HJD	β	HJD	β	HJD	β	HJD	β
2446949. +		2446949. +		2446949. +		2446949. +		2446949. +	
0.3867	2.786	0.4041	2.828	0.4233	2.790	0.4425	2.762	0.4618	2.753
0.3871	2.786	0.4046	2.827	0.4238	2.789	0.4430	2.754	0.4624	2.754
0.3876	2.792	0.4051	2.831	0.4243	2.795	0.4435	2.761	0.4629	2.757
0.3881	2.789	0.4055	2.844	0.4250	2.794	0.4440	2.755	0.4635	2.745
0.3891	2.803	0.4060	2.848	0.4257	2.782	0.4445	2.766	0.4640	2.740
0.3895	2.797	0.4103	2.838	0.4264	2.786	0.4450	2.753	0.4646	2.732
0.3914	2.794	0.4108	2.836	0.4292	2.782	0.4455	2.769	0.4651	2.736
0.3919	2.804	0.4112	2.831	0.4397	2.778	0.4460	2.754	0.4656	2.742
0.3924	2.799	0.4118	2.829	0.4302	2.781	0.4465	2.750	0.4661	2.743
0.3929	2.798	0.4123	2.830	0.4307	2.783	0.4471	2.748	0.4666	2.751
0.3934	2.804	0.4129	2.838	0.4311	2.782	0.4476	2.759	0.4672	2.752
0.3939	2.820	0.4133	2.835	0.4317	2.771	0.4481	2.769	0.4677	2.745
0.3944	2.824	0.4138	2.837	0.4322	2.767	0.4513	2.748	0.4683	2.729
0.3949	2.808	0.4143	2.832	0.4327	2.779	0.4518	2.756	0.4714	2.738
0.3954	2.808	0.4148	2.830	0.4332	2.781	0.4523	2.763	0.4719	2.748
0.3959	2.810	0.4153	2.823	0.4337	2.771	0.4528	2.753	0.4735	2.758
0.3964	2.830	0.4157	2.827	0.4347	2.760	0.4533	2.740	0.4740	2.759
0.3969	2.826	0.4162	2.821	0.4351	2.769	0.4539	2.738	0.4745	2.751
0.3974	2.828	0.4167	2.822	0.4356	2.776	0.4544	2.733	0.4750	2.744
0.3980	2.820	0.4172	2.809	0.4361	2.771	0.4549	2.748	0.4754	2.743
0.3985	2.815	0.4178	2.810	0.4368	2.773	0.4554	2.752	0.4759	2.749
0.3991	2.822	0.4184	2.805	0.4375	2.767	0.4560	2.763	0.4764	2.746
0.3995	2.824	0.4190	2.806	0.4382	2.761	0.4565	2.745	0.4769	2.737
0.4000	2.839	0.4195	2.799	0.4387	2.765	0.4569	2.736	0.4774	2.741
0.4005	2.832	0.4200	2.798	0.4391	2.769	0.4585	2.729	0.4779	2.753
0.4011	2.837	0.4205	2.805	0.4396	2.773	0.4590	2.728	0.4785	2.757
0.4016	2.827	0.4209	2.802	0.4401	2.768	0.4594	2.737	0.4790	2.752
0.4022	2.830	0.4214	2.803	0.4406	2.773	0.4599	2.725	0.4795	2.746
0.4027	2.833	0.4219	2.794	0.4411	2.762	0.4604	2.726	0.4816	2.759
0.4032	2.840	0.4224	2.797	0.4415	2.764	0.4609	2.730	0.4821	2.764
0.4036	2.838	0.4229	2.790	0.4420	2.759	0.4614	2.739	0.4826	2.762

TABLE 3

OBSERVATIONS OF 60-cm TELESCOPE

HJD	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV	HJD	ΔV
2447115. +		2447115. +		2447118. +		2447118. +		2447219. +	
0.5771	2.874	0.6571	2.735	0.6056	2.714	0.6926	2.909	0.5539	2.774
0.5826	2.903	0.6614	2.775	0.6089	2.643	0.6958	2.859	0.5581	2.674
0.5883	2.934	0.6806	2.911	0.6125	2.611	0.6989	2.791	0.5618	2.622
0.5926	2.963	0.6847	2.932	0.6163	2.624	0.7025	2.700	0.5656	2.622
0.5967	2.977	0.6888	2.954	0.6194	2.647	0.7059	2.644	0.5695	2.641
0.6025	2.994	0.6927	2.967	0.6230	2.676	0.7090	2.621	0.5724	2.673
0.6068	3.002	0.6968	2.985	0.6273	2.722	0.7121	2.625	0.5769	2.721
0.6104	3.004	2447118. +		0.6311	2.762	0.7156	2.650	0.5809	2.755
0.6141	2.998	0.5673	2.969	0.6373	2.814	0.7187	2.682	0.5852	2.793
0.6177	2.979	0.5708	2.981	0.6408	2.843	0.7233	2.722	0.5899	2.833
0.6233	2.935	0.5742	2.999	0.6443	2.867	0.7285	2.771	0.5941	2.858
0.6271	2.867	0.5778	3.008	0.6674	2.985	0.7320	2.802	0.5988	2.892
0.6311	2.785	0.5813	3.009	0.6716	2.992	0.7351	2.829	0.6034	2.923
0.6350	2.693	0.5846	3.007	0.6754	2.999	0.7382	2.849	0.6073	2.946
0.6388	2.630	0.5878	2.994	0.6784	3.000	2447219. +		0.6118	2.968
0.6437	2.617	0.5912	2.971	0.6815	2.995	0.5406	2.974	0.6161	2.980
0.6472	2.646	0.5988	2.880	0.6845	2.990	0.5448	2.945	0.6219	2.994
0.6531	2.700	0.6023	2.802	0.6877	2.968	0.5500	2.858	0.6288	3.015

TABLE 4

TIMES OF MAXIMA OF HD 79889

i	T_i (d) 2400000. +	E_i	O-C(d)	Obs
1	46498.3379	-4726	-0.0004	O87
2	46507.3501	-4632	0.0001	O87
3	46507.4459	-4631	-0.0000	O87
4	46508.4049	-4621	0.0003	O87
5	46509.4587	-4610	-0.0005	O87
6	46510.4175	-4600	-0.0004	O87
7	46524.4152	-4454	0.0004	O87
8	46950.4595	-10	0.0009	SN
9	46951.4174	0	0.0001	SN
10	47115.6420	1713	0.0003	SN
11	47118.6131	1744	-0.0005	SN
12	47118.7102	1745	0.0007	SN
13	47121.6813	1776	-0.0002	SN
14	47219.5637	2797	-0.0005	SN
15	47551.4645	6259	0.0003	SN
16	47551.5599	6260	-0.0002	SN
17	47551.6560	6261	0.0001	SN
18	47553.5729	6281	-0.0004	SN
19	47553.6692	6282	-0.0000	SN

number of degrees of randomness and choose the best one taking into account the factors of homogeneity and precision.

In this way, the times of maxima for HD 79889 have been calculated. When simultaneous photometry has been available each maximum has been derived as an average over the four *uvby* bands and the precision can also be tested by comparing the results obtained for each of the four filters. In all these cases the internal errors are less than $0.^d0005$. Also, both precision and homogeneity of the times of maxima calculated can be tested when the O–C method is applied and the residuals are obtained. These residuals are listed in the fourth column of Table 4 in days, and they are in very good agreement.

When the O–C method was applied to all the nineteen available maxima, taking as initial time our second light maximum, namely $T = 2446951.4174^d$, and as initial period $P = 0.0958697^d$, as given by Oja (1987), then the least square fit converged to

$$T_0 = 2446951.41733 \pm 0.00009 \text{ (HJD)} \qquad (1)$$

$$P_0 = 0.095869448 \pm 0.000000021 \text{ (days)}.$$

We have again applied the Fourier Transform method, prewhitening the frequency ν that corresponds to the derived period P_0. Again, the resulting periodograms did not show any trace of another frequency; moreover, these periodograms appear cleaner than those given above. In Table 5 are listed the amplitudes and phase-shift resulting from Fourier analysis for all four filters, considering truncated Fourier series up to 6 terms, and taking T_0 as initial time from equation (1). The number of the harmonic is listed in the first column. From Table 5 it is seen that the maximum light in the bands *v*, *b* and *V* occurs after that corresponding to the band *u* in about 0.016 cycles for the first and second harmonic. This effect is also noted for

TABLE 5

FOURIER ANALYSIS

	u		*v*		*b*		*V*	
H	A (mag)	φ (rad)	A (mag)	φ (rad)	A (mag)	φ (rad)	A (mag)	φ (rad)
ν	0.1827	4.341	0.2441	4.240	0.2136	4.239	0.1740	4.218
	9	5	6	2	5	3	6	4
2ν	0.0557	4.876	0.0743	4.664	0.0664	4.678	0.0548	4.667
	9	16	6	8	5	8	6	11
3ν	0.0194	5.234	0.0278	5.030	0.0238	5.035	0.0206	5.062
	9	45	6	21	5	22	6	29
4ν	0.0077	5.338	0.0116	5.346	0.0100	5.418	0.0084	5.398
	9	113	6	51	5	52	6	72
5ν	0.0034	5.709	0.0049	5.503	0.0041	5.618	0.0031	5.472
	9	255	6	121	5	129	6	194
6ν	...	...	0.0029	5.868	0.0022	5.912	0.0021	5.837
			6	203	5	236	6	282

the third harmonic. For the harmonics of higher order, the errors are too large. This effect can be explained in terms of temperature and log g variations. A detailed discussion can be found in Garrido, García-Lobo, and Rodríguez (1989*a*); Garrido and Rodríguez (1989*b*).

In Figure 1 the light and color-index variations of HD 79889 over the cycle of pulsation are shown. The short period and the form of the light curve suggests that HD 79889 can be classified as a "dwarf cepheid"(Breger 1980). The increasing branch is shorter than the decreasing one and the minimum light occurs about the phase 0.7. The curves for b–y and β are very close to the light curve since these two parameters are indicators of temperature. The curve in c_1 is also very close to the light curve, although the maximum in C_1 occurs after the maximum in V due to the phase-shift between the different colors mentioned before.

In order to decide if HD 79889 is a high amplitude δ Scuti star (belonging to population I) or an SX Phe star (belonging to an older population)

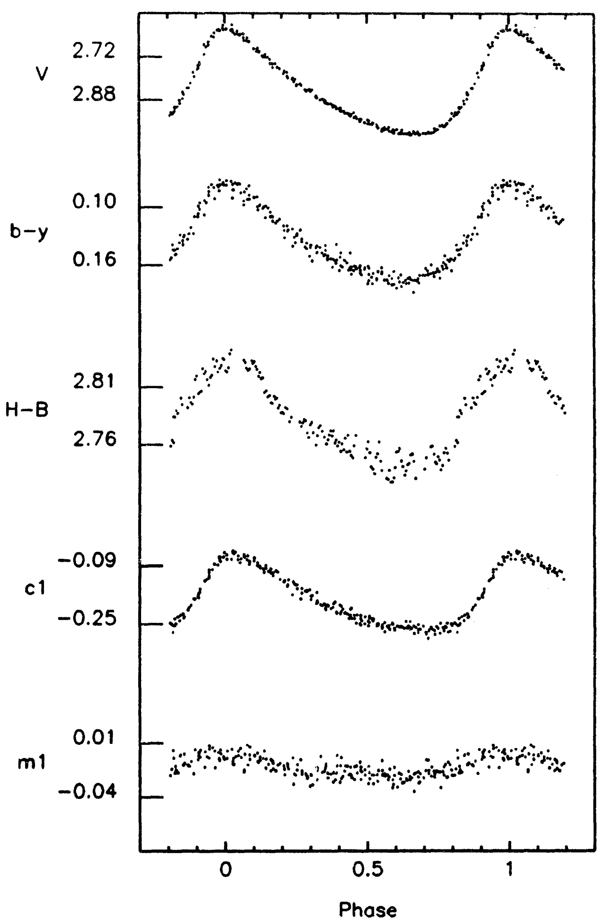

Fig. 1. Light and color-index variations of HD 79889 in the $uvby\beta$ photometric system over the cycle of pulsation.

the metallicity and/or, the space motion should be known. The space motion is not available, but Oja's discussion of proper motion suggests that HD 79889 is a high amplitude δ Scuti star.

Now, from Figure 1 it is shown that there is a variation in m_1 throughout the pulsation cycle. Available Strömgren photometry with good precision for high amplitude δ Scuti stars, for example, for AD CMi (Breger 1975; Rodríguez, López de Coca and Rolland 1988), DY Her (Breger, Campos and Roby 1978), VZ Cnc (Epstein and Epstein 1973), shows only a slight or no variation of the m_1 index over the cycle of pulsation. On the other hand, for example for the SX Phe stars CY Aqr (Van Citters 1976; López de Coca 1986), PY Peg (Van Citters 1976; McNamara and Feltz 1976), SX Phe (McNamara and Feltz 1976), KZ Hya (Przybylski and Bessell 1979; McNamara and Budge 1985), XX Cyg (Joner 1982), BL Cam (McNamara and Feltz 1978) this variation is significant. In this situation, it is possible that the behavior of m_1 in HD 79889 is that of a SX Phe star. However, it is obvious that the variation of m_1 in absolute value is only qualitative and must be tested with another parameter.

In this way, we can compare the variation of m_1 of the star with that inferred from the Hyades by the change in temperature over the cycle of pulsation (Breger 1980). That is, we are analyzing the variation of the parameter δm_1 (defined as δm_1 =

TABLE 6

PHOTOMETRY (NORMAL POINTS) OF HD 79889

Phase	V	b-y	m_1	c_1	β
0.00	8.583	0.107	0.172	0.961	2.833
0.05	8.598	0.111	0.169	0.960	2.833
0.10	8.646	0.122	0.166	0.945	2.829
0.15	8.688	0.133	0.162	0.926	2.811
0.20	8.736	0.145	0.160	0.902	2.793
0.25	8.782	0.155	0.157	0.875	2.783
0.30	8.815	0.164	0.156	0.855	2.774
0.35	8.848	0.172	0.154	0.836	2.768
0.40	8.879	0.178	0.153	0.814	2.764
0.45	8.907	0.184	0.152	0.798	2.757
0.50	8.929	0.189	0.151	0.781	2.753
0.55	8.948	0.193	0.151	0.771	2.745
0.60	8.964	0.196	0.150	0.767	2.739
0.65	8.971	0.194	0.152	0.765	2.743
0.70	8.969	0.190	0.153	0.764	2.745
0.75	8.950	0.186	0.155	0.765	2.748
0.80	8.909	0.175	0.158	0.772	2.763
0.85	8.840	0.157	0.164	0.796	2.786
0.90	8.744	0.137	0.170	0.846	2.812
0.95	8.627	0.113	0.171	0.923	2.826

m_1(Hyades)–m_1 (star) at the same temperature). It can be shown that the behavior of δm_1 is different for SX Phe and high amplitude δ Scuti stars (Rodríguez 1989). The variation of m_1 for a SX Phe star over a cycle of pulsation is always greater than that inferred from the Hyades, but this variation is always smaller for a high amplitude δ Scuti star. In this case, the behavior of δm_1 for HD 79889 is analogous to that of a high amplitude δ Scuti star.

In order to derive the reddening, temperature and gravity from the observed data, normal points were formed at phase intervals of 0.05 cycles, using cubic spline routines to fit the observational points. These normal points, are presented in Table 6. The V light curve (max 8.583^m, min 8.971^m), is in good agreement with that obtained by Oja (8.595^m, 8.995^m). From our values of (b–y), (0.107^m, 0.196^m), the corresponding values of (B–V) are 0.175^m and 0.297^m, (Cousins 1987), which compare very well with those obtained by Oja (0.180^m, 0.295^m).

A reddening of $E_{b-y} = 0.006^m$ was derived and the unreddened indices $(b{-}y)_0$, m_0 and c_0 were calculated from the relations given by Crawford (1975) in Philip, Miller and Relyea (1976). In this way, mean values of $\delta m_1 = 0.034^m$ and $\delta c_1 = 0.098^m$ were obtained. Since the derived values of δc_1 is much smaller than that limit $\delta c_1 = 0.281^m$ from Philip's calibration, we can conclude that this star is not too luminous and we can safely apply this calibration.

With these indices and by using Petersen's (Petersen and Jorgensen 1972) formulae, we find that the temperature of HD 79889 varies between 8130 K and 7380 K. The mean temperature, averaged over a pulsation period is 7690 K. On the other hand, we find that gravity varies from log g = 4.20 to log g = 3.84, with an average value of log g = 3.98. These temperature and effective gravity variations are plotted in Figure 2. This figure shows that large values for log g are present for phases between 0.8 and 0.95 corresponding to large outward accelerations. If we consider only the ones from 0.0 to 0.75, an average value of log g = 3.94 can be derived. By means of the formulae given by Crawford (1975) we obtain a $M_v = 1.9^m$ with $\sigma = 0.3^m$ over the pulsation cycle.

On the other hand, using the calibration for abundances from Nissen (1981) with $\delta m_{1min} = 0.031^m$ at minimum light (phases from 0.5 to 0.75), we obtain [Me/H] = –0.3; that suggests normal, near solar abundances for this star, typical of the high amplitude δ Scuti stars and opposed to the metal deficiency of the SX Phe stars.

In order to calculate the mass, radius, age and M_{bol}, the evolutionary tracks from Claret and Giménez (1989) have been used for X = 0.70 and Z = 0.02. In this way, a mass of 1.8(±0.1) $M_\odot$ and a radius of 2.4(±0.2) $R_\odot$ have been obtained in a very close post-main sequence state of evolution. The age corresponding to the position of this star in the log g-log T_{eff} diagram is 1.3(±0.2)×10^9 years and $M_{bol} = 1.6^m$(±0.2) in agreement with the above M_v within the error bars. In addition, we can check these values derived with the Period-Luminosity-Color relation for δ Scuti stars from López de Coca *et al.* (1989). In this way, the bolometric magnitude derived is M_{bol} = 1.66(±0.10).

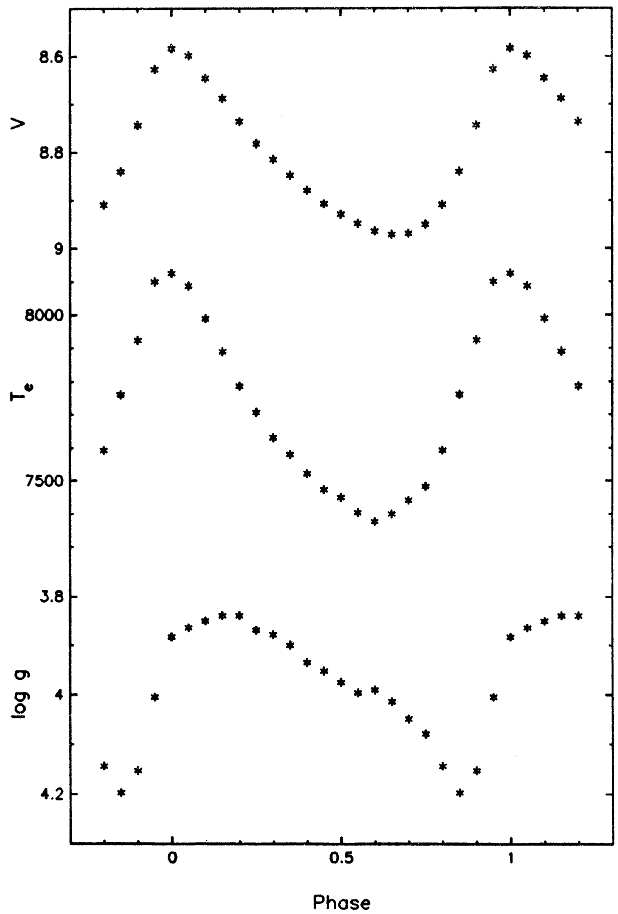

Fig. 2. Observed V, temperaturae and effective gravity variations of HD 79889.

A radius of 2.5(±0.1) $R_\odot$ has been calculated, by means of the formulae given by Moon (1984, 1985), for $(b{-}y)_0 \leq 0.335$ in good agreement with that mentioned above. Furthermore, we obtain a pulsation constant Q = 0.035, which although higher than normal, is not an unusual value for several other high amplitude δ Scuti stars (Rodríguez *et al.* 1988) and it can be considered as indicative of pulsation in the fundamental radial mode.

TABLE 7

PHYSICAL PARAMETERS FOR HD 79889

Parameter	Mean Value	Sigma	Error	Range
V	8.817	±0.130		8.583-8.971
E_{b-y}	0.006	±0.004		
$(b-y)_o$	0.154	±0.030		0.101-0.190
m_o	0.161	±0.007		0.152-0.174
c_o	0.840	±0.072		0.762-0.959
β	2.780	±0.033		2.739-2.833
T_e(K)	7690	±250		7380-8130
log g	3.94	±0.11		3.84-4.20
M_{bol}	1.6		±0.2	
$M(M_\odot)$	1.8		±0.1	
$R(R_\odot)$	2.4		±0.2	
Age(10^9 years)	1.3		±0.2	
d(pc)	280		±30	

A summary of the physical parameters of HD 79889 is presented in Table 7. In this table, the column with heading "sigma"lists typical deviations over the cycle of pulsation.

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