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ANALYSIS OF SELECT RR LYRAE STARS IN SERPENS FROM $uvby\beta$ PHOTOELECTRIC PHOTOMETRY

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RESUMEN

Se presenta un análisis de la fotometría $uvby\beta$ de la literatura de varias estrellas del tipo RR de Lira. A partir de éste, se determinan parámetros físicos $\log T_{\rm eff}$ y $\log g$ así como sus valores de metalicidad. Esta nos conlleva a la determinación de la magnitud absoluta M_v y se estima la distancia a cada estrella. Se proponen nuevas frecuencias de pulsación para dos estrellas.

ABSTRACT

A $uvby\beta$ photoelectric photometry analysis of several RR Lyrae stars in the literature was carried out. From it, the physical parameters $\log T_{\rm eff}$ and $\log g$ were determined as well as the metallicity. From the latter quantity, an M_v determination was carried out and a distance for each star was estimated. New frequencies are proposed for two stars.

Key Words: **STARS-VARIABLES, RR LYRAE — PHOTOMETRY**

1. INTRODUCTION

Cox (1974) said that most of the pulsating stars lying in a clearly defined oval region in the HR diagram (RR Lyrae variables, Classical Cepheids, W Virginis variables, Dwarf Cepheids and Delta Scuti variables) were thought to owe their instability to a common physical mechanism. He referred to this oval region as the "instability strip" or "instability region", and he emphasized that the classification of pulsating stars into distinct groups has some basis in reality. Since these early concepts, much has been done in the field of variable stars, but much still remains to be done.

The RR Lyrae stars are known to serve as distance indicators and test probes against which already developed theoretical models have to be compared. The data of some of these stars are presented here; some have been previously published. Since each star has its own characteristics with respect to period, luminosity, temperature and chemical composition, the observational problems encountered for each one are different. However, as has been stated by Jacoby et al. (1992), *"with only two colors it is not possible to estimate the reddening for individual stars and hence the most common expedient has been to adopt a global reddening correction."* Since this latter difficulty can be overcome by the simultaneous photometry attainable at the Observatorio Astronómico Nacional in México, a program was developed with the aim of acquiring $uvby\beta$ photometric data of the aforementioned variable stars that could become important and numerous enough to be useful, and that serve to test the derived period-color, M_v – [Fe/H], $M_v - T_{\rm eff}$, etc. relationships as well as for the obtainment of their physical parameters. A similar analysis was done by Van Albada & de Boer (1975), pioneers who carried out this analysis of four RR Lyrae stars.

A summary of what we have done follows:

1. We have determined the reddening, the unreddened colors and the metallicity as a function of phase from the $uvby\beta$ data of each star, utilizing Nissen's (1988) relations.

2. In the case of AP Ser, new ephemerides were calculated due to the evident phase shift with respect to the reported periods proposed by Kholopov (1985) and Lub (1977). A similar situation, although not so pronounced, was found for AV Ser.

3. From the metallicity, a determination of M_v was done with Feast (1997), McNamara (1997),

Carreta et al. (2000), Gratton et al. (1997), and with Groenewegen & Salaris' (1999) relations, but in order to avoid confusion with the values obtained due to the shock waves at times of maximum, only those values of [Fe/H] at minimum light were considered.

4. Once M_v was known, the distance to the star was determined.

5. From the reddening determined from the photometry at values at minimum light, average reddening was considered and from it, unreddened indexes were calculated that, via Lester et al.'s (1986) grids, helped determine the physical quantities $\log g$ and $T_{\rm eff}$ both at minimum phase values and around the whole cycle to determine the real physical variations around the cycle, a procedure that had not often been done on these stars. Other temperature values were obtained from McNamara (1997)

In summary, we have determined the following for each star: reddening $E(b{-}y)$, metallicity [Fe/H], M_v, distance, and the physical quantities $\log g$ and $T_{\rm eff}$. These values will serve to establish useful relation for RR Lyrae stars.

2. DATA

The observational data employed in the present paper were gathered at the SPM observatory in Baja California, México and most of them were presented in Peña, Diaz, & Peniche (1990). The dates of observations and characteristics of the observed stars are presented in Table 1. Column 1 list the ID, column 2, the type of RR Lyrae star according to Kholopov (1985), columns 3 and 4 the amplitude and ΔS values from Lub (1977), column 5 the epoch, columns 6 and 7 the reported periods; another source of assigned periods is that of Bookmeyer et al. (1977) but theirs are basically the same as those of Lub (1977) and for only three stars; the average date of the data is listed in column 8 and in columns 9 and 10, the elapsed time between the epoch and the time of the acquisition of the data are presented.

These data have the advantage that they were obtained with the Danish spectrophotometer simultaneously in the *uvby* filters and almost simultaneously in the narrow and wide filters that define β, avoiding the necessity of phasing the data, which is troublesome in particular for short period, multi-periodic variable stars or for certain phases of variable stars which change their behavior dramatically in short periods of time as is the case of the steep rise towards the maximum light for some $RR_{\rm AB}$ stars. The final photometric results in the absolute $uvby\beta$ system were presented in Table 6 of Peña et al. (1990) and the RR Lyrae star for which the data have not yet been published, BT Ser, is listed in Table 2. The same transformation coefficients and uncertainties calculated and presented in Peña et al. (1990) are valid for these data. Phase diagrams were obtained for each star; in the determination of the phase we employed the ephemerides of Kholopov (1985), although in some cases, as in Peña et al. (1990), the ephemeris proposed by Lub (1977), is listed in Table 1. A few comments on the results for each RR Lyrae star were given in Peña et al. (1990) and are still valid.

To our knowledge there is just one other source with Strömgren $uvby\beta$ photometry but for only two of these stars: AN Ser and VY Ser: a paper by Eggen (1994). He presents a large list of 43 observed RR Lyrae stars; unfortunately, the amount of time devoted to each star is limited and the elapsed time between the observations, large, but his observations can serve as an indicator of the gross behavior of the data as well as a source of verification of the data we are dealing with.

The comparison of AN Ser with Eggen (1994) is excellent. Basically there is no difference in V and $b-y$; his m_1 data are rather noisy and do not follow the phase trend and there is only a significant difference for the only point beyond phase 0.8; for the rest the difference was minimal. His β values were within the large scatter of the values of Paper I. One has to keep in mind that Eggen's data consisted of only six points obtained in a time span of 75 days. The comparison of VY Ser with Eggen's (1994) data in the $b-y$ index fits perfectly, as well as the V mag, but some color indexes yield larger than expected differences, particularly in the c_1 index, of 0.1 mag, and in β of a systematic difference of 0.03. Three out of eight of his m_1 index values do not follow the phase pattern. Eggen's (1994) VY Ser data consisted of only 7 points in 29 days and another one, 1352 days apart which does not explain the difference because the phasing in both sets is adequate. The relatively small difference between the two sets should rest then in the transformations into the standard system which he does not provide.

As was already mentioned, there were some peculiarities with several stars. These will be described below.

2.1. *Period Determination of AP Ser*

Several points need to be mentioned: in the first place, taking either of the ephemeris proposed,

TABLE 1

EPHEMERIDES OF THE OBSERVED RR LYRAE STARS

ID	Type (1)[a]	ΔV (2)[b]	ΔS (2)[b]	Epoch (1) 2400000+	Period (2)[b]	Period (1)[a]	Time (3)[3]	ΔT (yr)	Elapsed cycles
AN Ser	AB	0.427	0	14708.950	0.52207070	0.52207162	46963	88	61781
AP Ser	C	0.199	8	28334.279	0.2541180	0.34132	46963	51	54578
AT Ser	AB	0.376	9	41798.579	0.74656820	0.7465465	46963	14	6918
AV Ser	AB	0.460	6	28343.337	0.4875571	0.48755736	46963	51	38190
BH Ser	AB			41482.427		0.4345527	46962	15	32555
BT Ser	···			32820.307		0.295480	46967	39	47877
CS Ser	AB			31176.430		0.5267959	46963	43	29967
VY Ser	AB	0.292	9	31225.341	0.7140931	0.71409384	46963	43	22039

[a]1. Kholopov (1985).

[b]2. Lub (1977).

[c]3. Shown time = ⟨Date obs⟩ − 2440000.

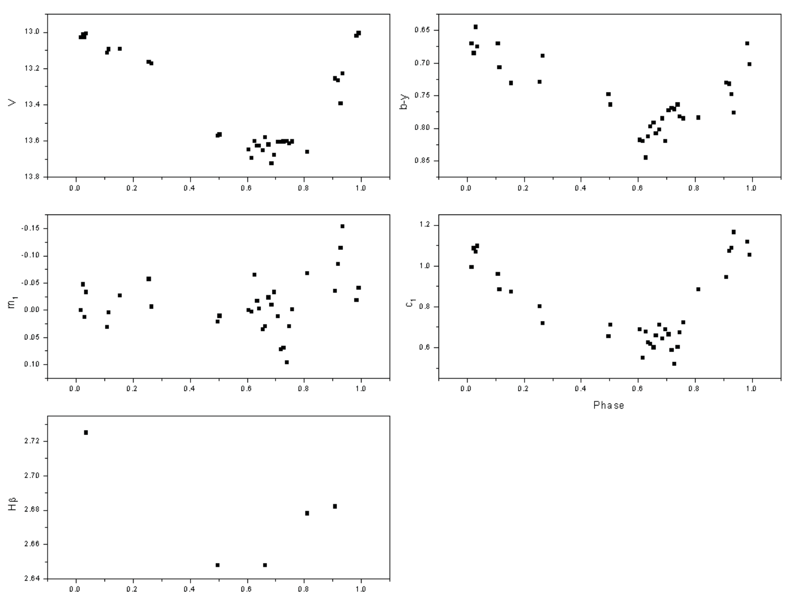

Fig. 1. Strömgren $uvby\beta$ time variation in phase of the BT Ser RR Lyrae star for a period of 0.295480 d.

Kholopov's or Lub's, the maximum value of the Peña et al. (1990) list does not correspond to phase zero implying, of course, an inaccurate determination of the period or, less probably, a period variation. The elapsed time of observations is significant, 51 years, and a careful $O-C$ would provide a better period determination. Second, its soft behavior implies the nature of an RRc type variable as it has already been classified. Clearly discernible in the color indexes $b-y$ and in c_1 is a standstill just before the maximum value. The time coverage along the cycle is rather complete particularly at the time of minimum which

TABLE 2

$uvby\beta$ PHOTOELECTRIC PHOTOMETRY OF THE BT SER STAR

V	$b-y$	m_1	c_1	HJD	Hβ	HJD
13.647	0.818	0.000	0.687	2446964.8180		
13.695	0.820	0.003	0.550	2446964.8212		
13.600	0.845	−0.065	0.678	2446964.8244		
13.628	0.813	−0.017	0.624	2446964.8269		
13.628	0.797	−0.003	0.617	2446964.8290		
13.651	0.792	0.036	0.600	2446964.8327		
13.581	0.808	0.030	0.657	2446964.8350	2.648	2446964.8375
13.620	0.802	−0.023	0.711	2446964.8386		
13.725	0.785	−0.010	0.643	2446964.8416		
13.677	0.820	−0.033	0.688	2446964.8447		
13.606	0.773	0.012	0.664	2446964.8481		
13.604	0.769	0.072	0.586	2446964.8513		
13.603	0.771	0.069	0.518	2446964.8541		
13.602	0.764	0.096	0.601	2446964.8575		
13.615	0.782	0.030	0.672	2446964.8597		
13.603	0.785	−0.001	0.722	2446964.8632		
13.256	0.730	−0.035	0.944	2446965.7941	2.682	2446965.7975
13.266	0.732	−0.084	1.074	2446965.7972		
13.392	0.748	−0.114	1.089	2446965.7998		
13.228	0.776	−0.154	1.165	2446965.8020		
13.030	0.670	0.000	0.995	2446965.8259		
13.014	0.685	−0.047	1.086	2446965.8283		
13.028	0.645	0.013	1.068	2446965.8299		
13.007	0.675	−0.033	1.097	2446965.8317	2.725	2446965.8484
13.573	0.748	0.021	0.654	2446967.7407	2.648	2446967.7411
13.565	0.764	0.011	0.710	2446967.7428		
13.662	0.784	−0.067	0.885	2446967.8337	2.678	2446967.8630
13.166	0.729	−0.057	0.800	2446967.9648		
13.174	0.689	−0.006	0.720	2446967.9679		
13.020	0.670	−0.018	1.117	2446968.7709		
13.006	0.702	−0.041	1.055	2446968.7732		
13.115	0.670	0.031	0.959	2446968.8080		
13.095	0.707	0.004	0.885	2446968.8096		
13.094	0.731	−0.026	0.873	2446968.8215		

will serve to calculate its physical parameters. To complicate the matter, there is a discrepancy among the periods reported in the literature: Kholopov's period is 0.34132 d whereas Lub reports 0.254 d. Evidently, there is an aliasing problem. To throw light on this matter we did the following: from the observed data in Peña et al. (1990), we determined the time of occurrence of the two maxima, at 65.7365 and 67.7799 d; if we consider the elapsed time between these maxima, both reported periods correspond to 8 cycles for Lub's period and to 6 cycles for Kholopov's period. Hence, that criterion does not distinguish between the periods. A rapid period analysis with two methods, PERIOD (Breger 1991) and MUFRAN (Kollath 1990) gave, for the short time span observed by Peña et al. (1990), the maximum peak at the frequency 2.939 c/d with a large amplitude value, of 0.2215 mag; the next peak was at 1.811 c/d with an amplitude of 0.023 mag; of course the alias could correspond to Lub's period. Nevertheless, assuming the outputs of both methods are valid, which, by the way, correspond to the reported value of Kholopov (1985), a mere $O-C$ value between Kholopov's (1985) ephemeris of 28334.279 d modified the period from 0.34132 d to 0.34131675 d to get again the maxima at phase value of zero if we assume an overestimation of the period. It is useless to say that the change, although apparently insignificant, propagated on a time basis of 51 years, becomes important as has been shown.

AV Ser. It shows a significant shift in the time of maximum which varies from 0.1 in V, 0.12 in $b-y$ and 0.17 in c_1. The m_1 index, as expected, shows a much less pronounced maximum which does not allow its accurate determination. An adjustment of the period with only three times of maximum light could be significant, since the elapsed time of 51 years does not phase the data well to the new observations. In view of the several unsuccessful attempts to phase the data, we carried out a period analysis of the scarce data of 4 nights in the PERIOD package (Breger 1991). This numerical code gave 3.06675 c/d as the frequency with largest peak. Utilizing the residuals after the fit as a numerical discriminator between the two frequencies, the best fit was obtained, with the scarce data available with the frequency found by PERIOD. The phasing of the data with the ephemeris of Kholopov and this period phase the data correctly. There is, of course, the need for more data since an accurate determination of the period requires many more times of determined maxima than those currently available, or longer data strings than those utilized to determine the period.

BH Ser This star was observed only for two nights and the data barely cover a whole cycle. Nevertheless, enough data points were available to describe the phase of minimum. The occurrence of maximum light happens a little bit before, implying a need for correction of the period but since the change is so small, we preferred to leave it as it was.

CS Ser The time of occurrence of the maximum is before the zero phase value, indicating a slight underestimation of the period; this occurrence is the same for the magnitude as well as for the color indexes and would provide a small change in the period because the time difference between the ephmerides and the observed time is of 43 yr. Due to its rapid and steep rise, there is a gap between phases 0.8 to 0.9 which does not jeopardize the averaging of the photometric values to determine its characteristics. No new period determination was done.

2.2. *Hβ determination of BT Ser*

This star was observed for just four almost consecutive nights and due to the window of observation as well as the period, 0.295480, the data consists of two nights with points around the minimum light and two near the maximum. Its faintness, at around 14 magnitude at minimum light make the data quite noisy. The time of maximum coincides with phase zero implying a constant period in a time span of 39 yr. However, basically no data points in the Hβ index were acquired. In view of this fact, and since the observed points were adequately in phase with the rest of the indexes, a third degree equation $Y = 2.74037 - 0.44331\ X + 0.61416X^2 - 0.21309X^3$ was fitted to the data and the Hβ values were interpolated. We propose that this star, whose RR type is not listed neither by Kholopov, Lub, or Bookmeyer, is an AB type. We are basing our assumption on the steep rise of the variable and on the large amplitude of variation in the V filter (Figure 1) although its period is rather short, merely 0.295480 c/d, which corresponds to a RRc type star.

3. PHYSICAL PARAMETERS

Once the unreddened colors for the stars have been determined, Strömgren photometry provides unique possibilities for determining physical parameters by direct comparison with theoretical models like those proposed by Lester, Gray, & Kurucz (1986) for different metallicities, some which are characteristic of the RR Lyrae stars. Hence, as a first step, the determination of the reddening, as well as the determination of the metallicity has to be tackled. In order to reach this goal, we have employed the calibration proposed by Nissen (1988) for A and F stars, to which the RR Lyrae stars belong and that has been extensively employed and has already been described (see for example Peña, González, & Peniche 1999).

However, in order to determine some significant physical parameters as Breger (1978) and McNamara (1997) proposed, we restricted the analysis of some characteristics of the stars to the descending branch and the minimum in the light curves, in the phase intervals around 0.2 to 0.8. The limits of the phase values themselves were selected directly for each star from the light curves. As stated before, the ephemerides of Kholopov (1985), and of Lub (1977) were employed, Table 1, except, of course, for AP Ser.

These photometric values, arranged by decreasing Hβ values were analyzed through the already mentioned Nissen (1988) calibrations that provided us with the reddening, the unreddened colors and the metallicity. These values were obtained for each set that had a corresponding Hβ value. Then, mean values were calculated but, as has been repeatedly said, only the values in the descending branch or the minimum values were considered and are listed in Table 3. Hence, caution should be taken because these are not the color indices along the cycle nor the V_0; the content of each column does not need any description. The standard deviations obtained are also listed.

These mean metallicity values for each star served to calculate the M_v for each one using the calibration of Feast (1997); his equation (4) $M_v = 0.37$ [Fe/H] $+ 1.13$ which, as he states, 'serve(s) to derive values of M_v and hence distances' was employed.

For RR Lyrae stars there have been, besides the relation proposed by McNamara (1997) $M_v = 0.287$ [Fe/H] $+ 0.964$, some other empirical calibrations, among others, the relation (which is period dependent) from Hipparcos $M_v = -3.74 \log P - 1.91$. More recent evaluations of the M_v for RR Lyrae stars have been developed in, among others, the work of McNamara (2001, $M_v = 0.30$ [Fe/H] $+ 0.92$), which is based mainly on the results derived from globular clusters, of Carreta et al. (2000; $M_v(RR) = 0.18([\mathrm{Fe/H}] + 1.5) + 0.73$), of Gratton et al. (1997; $M_v(RR) = (0.22([\mathrm{Fe/H}] + 1.5) + 0.43)$ and of Groenewegen & Salaris (1999; $M_v = 0.18[\mathrm{Fe/H}] + 0.77$) which are based on the Hipparcos parallaxes. The results of the considerations of them are presented in Table 4.

With respect to the reported metallicities we have compared the derived values with the ΔS value of Preston (1959) reported by Hemenway (1975) and Suntzeff, Kraft, & Kinman (1994) or Lub (1977) for RR Lyrae stars, among them, a few of the reported stars in Serpens. The first source provides only mean ΔS values, whereas the latter gives wider time coverage, particularly for AN Ser and AT Ser. Calculating the phases with the same ephemerides that are reported in Table 1, we have compared the ΔS values with those [Fe/H] values derived here. The behavior of both metal content indexes for the AN Ser star is remarkable as can be seen in Figure 2. No such good agreement was obtained for the AT Ser star due mainly to the large scatter shown in the ΔS spectral index. The overall behavior of all five stars, although with 18 data points, (Figure 3) is

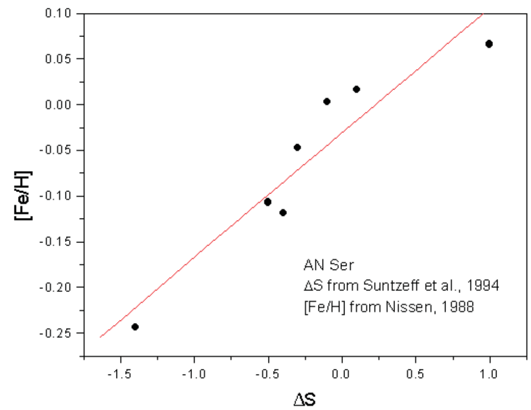

Fig. 2. ΔS values compared with those [Fe/H] values derived here for equal phases calculated the same ephemerides that are reported in Table 3. The behavior of both metal content indexes for the AN Ser star is remarkable, as can be seen in this figure.

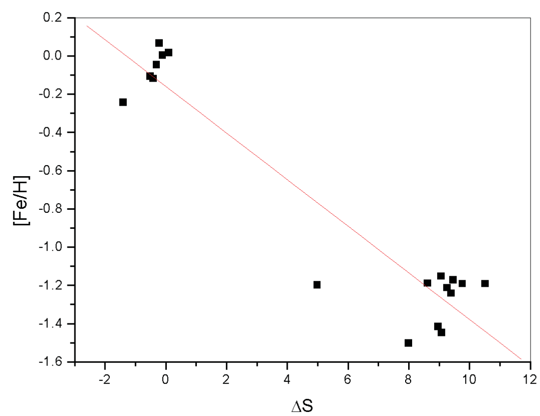

Fig. 3. The overall behavior of all the five RR Lyrae stars with Preston's ΔS spectral index with the metallicity [Fe/H].

[Fe/H] $= -0.1584 - 0.12194 \times \Delta S$ with a correlation coefficient R of 0.95.

The temperatures are determined in two ways: first, through the calibrations proposed by McNamara (1997) and, second, from the theoretical $uvby\beta$ indexes by Lester et al. (1986) calculated for $uvby$ indexes for several values of metallicities. In the first case, McNamara (1997) proposes a relation $\langle T_{\mathrm{eff}} \rangle = -1039 \log P + 6467$ in his equation (1) and $\langle T_{\mathrm{eff}} \rangle = 108$ [Fe/H] $+ 6874$ in his relation (3). The

TABLE 3

REDDENING AND UNREDDENED INDEXES AT MINIMUM LIGHT FOR THE RR LYRAE STARS CONSIDERED

ID	$E(b-y)$	$(b-y)_0$	m_0	c_0	Hβ	V_0	[Fe/H]
AN Ser	0.047	0.294	0.169	0.722	2.646	10.995	−0.034
σ	0.021	0.029	0.010	0.057	0.023	0.166	0.144
AP Ser	0.014	0.217	0.057	0.988	2.676	11.215	−1.431
σ	0.007	0.029	0.009	0.095	0.032	0.127	0.168
AT Ser	0.040	0.270	0.063	0.748	2.624	11.392	−1.241
σ	0.012	0.013	0.004	0.049	0.013	0.087	0.046
AV Ser	0.037	0.300	0.170	0.709	2.641	11.017	−0.028
σ	0.019	0.020	0.007	0.027	0.016	0.131	0.101
BH Ser	0.017	0.240	0.105	0.874	2.671	12.678	−0.782
σ	0.021	0.033	0.041	0.121	0.026	0.159	0.577
BT Ser	0.507	0.285	0.165	0.542	2.655	11.444	−0.011
σ	0.032	0.011	0.032	0.054	0.005	0.127	0.395
CS Ser	0.053	0.275	0.075	0.666	2.628	12.487	−1.129
σ	0.025	0.022	0.010	0.047	0.026	0.093	0.110
VY Ser	0.035	0.295	0.072	0.682	2.599	10.089	−1.193
σ	0.006	0.007	0.003	0.030	0.008	0.066	0.033

values which arise from the period and metallicity for each star are listed in columns 7 and 8 of Table 4 and denoted by Mc(P) and Mc(Fe); the assigned periods and the mean metallicity value were considered. The remaining columns of Table 4 consider the following: column 1, the ID number, column two, the metallicity [Fe/H]. column 3 the log of the period, column 4 the M_v from Feast, column 5 the distance modulus, and column 6 the distance; the following columns 7^{th} to 11^{th}, the T_e calculated in different manners: from the relation of MacNamara using the period and the metallicity; the following ones, from the relations of Lester at times of maximum and minimum light; at the temperature at minimum phase, and finally, the log g value at maximum and at minimum light from their position in the grids of Lester et al. (1986).

On the other hand, the grids of $(b-y)_0$ vs. c_0 from the numerical output of Lester et al. (1986) were constructed for the metallicities calculated for each star and listed in Table 3 and shown for CS Ser in Figure 4. Then, the unreddened indexes for each $(b-y)_0$ vs. c_0 point provided both the T_{eff} and the surface gravities determined with the advantage that they are calculated along the cycle of pulsation whereas with the mean values, they are not. Table 4 in columns 9 to 13 lists the obtained results for the stars considered at maximum and minimum. We must call attention to the fact that the values

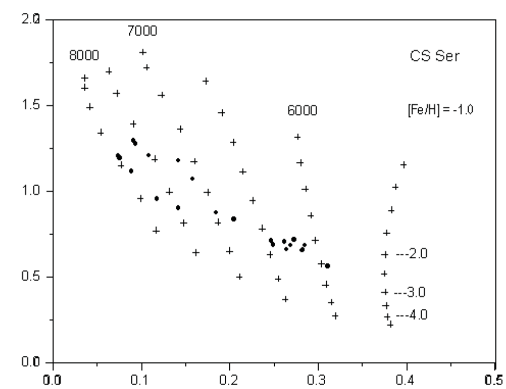

Fig. 4. Location of the unreddened indexes $(b-y)_0$ vs. c_0 for the RR Lyrae star CS Ser in the theoretical grids of Lester et al.(1986) for an [Fe/H] $= -1.0$.

determined from the relations of McNamara (1997) are within the limits derived from those determined from the location of the unreddened indexes in the grids of Lester et al. (1986). Finally, column 11 lists the mean effective temperature of all the values calculated for all phases. The last two columns provide the range of variation of the surface gravity.

TABLE 4

PHYSICAL PARAMETERS DERIVED FOR THE RR LYRAE STARS

ID	[Fe/H]	$\log P$	M_v Feast	DM	Dst (pc)	T_e Mc(P)	T_e Mc(Fe)	T_e max Lester	T_e min Lester	T_e phase	$\log g$ max	$\log g$ min
AN Ser	−0.034	−0.282	1.117	9.70	870	6760	6870	7600	6100	6250	3.2	2.5
AP Ser	−1.431	−0.467	0.601	10.46	1240	6950	6730	7400	6400	6500	3.0	2.2
AT Ser	−1.241	−0.127	0.671	10.69	1380	6600	6740	7400	5400	6250	3.3	2.5
AV Ser	−0.028	−0.312	1.120	10.00	1010	6790	6870	7400	5700	6200	2.6	1.5
BH Ser	−0.782	−0.362	0.841	11.69	2190	6840	6720	7400	6200	6400	3.0	2.2
BT Ser	−0.011	−0.529	1.126	10.10	1050	7020	6870	7500	6000	6370	4.1	3.0
CS Ser	−1.129	−0.278	0.712	11.42	1950	6760	6750	7800	6000	6200	3.3	2.6
VY Ser	−1.193	−0.146	0.689	9.34	740	6620	6750	6800	5900	6000	3.2	2.5

To calculate the distances from a unique mean absolute magnitude we should calculate the distance from an equally representative value of apparent magnitude; hence, we have several options: average values as we have done would provide only values at time of minimum and hence a biased value of the distance. More representative values are obtained once the reddening is determined by considering mean values of the reddening and utilizing the unreddened V_0 for the whole cycle; then, although the scatter effect of the distance obtained is large, it is artificial and merely due to the large amplitude of variation of the stars with respect to only one value of M_v the mean value; however, this value, averaged along the cycle, gives a representative value of the distance to the star. These values of the distances to the stars are presented in columns 5 and 6 of Table 4. The columns before them list the ID, the determined metallicity, the log of the period and the M_v determined from the Feast (1997) relation.

4. RESULTS

How well do the results fit the current knowledge about RR Lyrae stars? As has already been mentioned, although there is, apparently, a large discrepancy between the temperatures obtained from McNamara's relations and Lester et al. (1986) grids, in reality there is adequate agreement because the latter brackets those obtained from McNamara relations. However, when we compare the outputs of the three methods, in those stars that have their temperatures determined by McNamara's (1997) metallicity relation, there are two discordant stars, AN Ser and AP Ser, which do not follow the pattern of the other methods to determine the temperatures of the stars. A correction is done in the case of AP Ser since it is not an AB RR Lyrae star but a c type. In view of this, since McNamara's log $P - T_e$ relation applies to fundamental mode periods, and since an RRc type star is pulsating in the first overtone mode, to put log P (RRc) in the same system, the quantity 0.127 was added. Hence, in order to verify the temperatures assigned to each star, different discriminators can be employed. Since in the A to F spectral range β is the primary temperature discriminator, correlations between β and the obtained temperatures at the times of minimum light for each star were looked for. With the techniques proposed by McNamara (1997) we found a linear relation from the temperatures obtained from the period, but no trend at all from those obtained from the metallicity. A clear linear relation is very well marked for those temperatures at minimum light determined using the grids of Lester et al. (1986). We must emphasize that these temperatures were determined from the $(b-y)_0$ vs. c_0 indexes, and that now a completely differently determined index, Hβ, serves as an independent method of verification putting the output in a consistent frame (Figure 5).

5. CONCLUSIONS

At this stage, we can conclude that the aims we intended to accomplish were achieved. Reddening and unreddened indexes were obtained for each star; new periods were determined for AP Ser and AV Ser that give a correct phasing considering the ephemeris of Kholopov (1985) that corresponds to an elapsed time of the observations of 51 years. We have determined the M_v for each star and from it, the distance to each. Finally, we have determined the log g and the effective temperature with three methods which converge if we keep in mind the large amplitude variations of the stars.

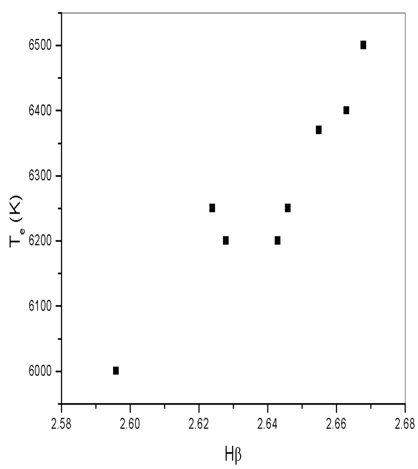

Fig. 5. A clear linear relation is very well marked for those temperatures at minimum light determined using the grids of Lester et al. (1986) with different temperature indicators such as a differently determined index, Hβ.

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