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$uvby-\beta$ PHOTOMETRY OF THE RR LYRAE STAR AC AND

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RESUMEN

Se presenta tanto fotometría diferencial como Strömgren $uvby-\beta$ de la estrella AC And. Del análisis de estos datos, así como de los de la literatura, se corroboran los períodos propuestos por Fitch & Szeidl (1976). La fotometría de Strömgren se ha utilizado para la determinación del enrojecimiento y de los parámetros físicos $\log g$ y $\log T_e$ así como la metalicidad [Fe/H]. Se discute la determinación de M_v y, en base a los resultados, proponemos a AC And como una estrella del tipo RR de Lira de posible composición química anormal.

ABSTRACT

Strömgren $uvby-\beta$ and differential V photoelectric photometry of the variable star AC And is presented. Analysis of this data, as well as data from the literature, corroborates the periods proposed by Fitch & Szeidl (1976). Strömgren photometry has been used for the determination of the reddening and the physical parameters $\log g$ and $\log T_e$, as well as the metallicity [Fe/H]. The determination of M_v is also discussed and, in view of the results, we propose that AC And is an RR Lyrae star with possible anomalous chemical composition.

Key Words: **STARS: VARIABLES: DELTA SCUTI — STARS: VARIABLES: RR LYRAE — TECHNIQUES: PHOTOMETRIC**

1. INTRODUCTION

The nature of AC And has been disputed. The variable star catalogue (Kholopov 1985) lists the following for AC And: V variation within the range $10.6 \rightarrow 11.6$ with a spectral class A9–F8 and classified as a unique variable star outside the range of the canonical classification. It probably represents the short stages of transition from one variability type to another. On the other hand, Simbad reports it to be a variable star of the RR Lyr type with an V mag of 10.8 and a spectral type of F5; other sources such as Rodríguez (2002), define it as the prototype of its own class.

Based only on previous observational data, Rodríguez (2002) states that it may be "the link between the δ Scuti and the classical Cepheid variables". However, there is previous contradictory research into the nature of this star; those in favour of a RR Lyrae classification include Fernie (1994), Berdnikov (1993), and Jakate (1978). Those in favor of a δ Scuti nature are Fitch & Szeidl (1976, hereafter F&S 76), Kovacs & Buchler (1994, hereafter K&B 94). Finally, there are those studies which do not reach any conclusion at all: Petersen (1990), Rodríguez & Breger (2001), and Schmidt (2002).

The analysis presented here was motivated by the work of K&B 94, and Fernie (1994). In the latter reference, Fernie (1994) suggests that it would be extremely useful to have new photometry, carried out in "the Strömgren or Geneva systems", that would provide checks on the metallicity, luminosity, temperature, etc., of AC And. This same proposal was suggested by K&B 94 who, unable to reach a definite conclusion from the available data, encouraged the acquisition of multicolor photometry to improve the knowledge of the chemical composition, temperature, and luminosity. They suggest a period study of the already existing data in combination with new observations. With the goals of K&B 94 and Fernie (1994) in mind, an analysis of the data of two photometric campaigns of AC And (1992 in $uvby-\beta$ and in 1998 in V) was carried out.

Considering AC And to be either an RR Lyrae star or a δ Scuti star since its true nature has not

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been resolved, we have calculated its reddening by several methods, and hence derived its unreddened colors. Physical parameters have been calculated for both previously assumed types of star. Period analysis of the data in this paper as well as those of the literature (as K&B 94 suggested) has been carried out confirming the results of F&S 76. From this analysis we will conclude that AC And must be an RR Lyrae star.

2. OBSERVATIONS

The observations were carried out at the Observatorio Astronómico Nacional, México. The telescope employed in the first campaign was the 1.5 m telescope to which a spectrophotometer was attached. The description of the photometric equipment can be found in Schuster & Nissen (1988). In a separate observing run (in 1998), another telescope, the 84 cm telescope with a one-channel photomultiplier with a V filter was utilized.

2.1. *Differential V Photometry*

Differential photometry was done in the customary way using the brightest star, SAO 52878, located near the variable, as a comparison star. Each one of the reported values is the result of averaging three measurements of 10 s for each star from which a 10 s integration of the sky was subtracted. The accuracies obtained were 0.004 in magnitude and 0.001 days in time. The observed values are presented as the difference (variable minus comparison) and no zero baseline was calculated to be able to discern the beating of the variable. The results for ΔV are presented in Table 1 (available in the electronic version).

2.2. *Absolute $uvby-\beta$ Photometry*

The instrument utilized was a spectrophotometer that allows the simultaneous acquisition of radiation in the *uvby* filters that define the Strömgren system. Almost simultaneously, radiation counts in two more filters can be obtained in the N (narrow) and W (wide) bands that measure the Hβ strength. This instrument is particularly suited for observing multi-periodic variables since it avoids data phasing in different colors which might introduce incorrect results. Furthermore, Strömgren photometry provides a safe method for determining the absolute magnitude of main sequence stars which might be applicable if we assume AC And is a possible δ Scuti star. This method is basically an extension of Crawford's calibrations (Crawford 1975, 1979; Crawford & Mander 1966) for A and F stars (the range of validity for variable stars within the instability strip limits) using a technique modified by Nissen (1988) (see Peña & Peniche 1994 for details). This technique provides the reddening, unreddened colors, distance and, equally important, provides a measure of the metallicity, [Fe/H] which, as K&B 94 stated, is crucial for modelling. Furthermore, if an accurate determination of the period is to be done, new and continuous data will always be of great value. We have carried out an independent period analysis of the available data to check the periodic content of the star. The reduction to the instrumental system has been described in previous work (see Peña & Peniche 1994) and followed the method utilized by Grönbech, Olsen, & Strömgren (1976). Each measurement consisted of five ten-second integrations of each star and one ten-second integration of the sky for the *uvby* filters and five ten-second integrations for the narrow and wide filters, with one ten-second integration of the sky. The percentage error in each measurement of AC And is $\delta(u, v, b, y, N, W) = (0.009, 0.006, 0.005, 0.008, 0.013, 0.012)$ magnitudes and the accuracy in time is 0.0015 days. A set of standard stars was observed in order to transform the instrumental observations into the standard systems. The transformation from the instrumental system to the standards was done with the computing package of Arellano-Ferro & Parrao (1988). Most of the standard photometric values utilized for the transformation were taken from Olsen's list (1983). The final accuracy of the season has been obtained from a direct comparison of the photometric values from the standard stars compared to the values from the literature. A linear fit of our data versus the published values gives the coefficients shown in Table 2 for the magnitude and color indexes, where A and B are the abcissa and the slope of the linear fit and R is the correlation coefficient. N is the number of data points employed. These values of A and B are really the transformation coefficients, and R can be considered as a measure of the accuracy of the linear fit.

The final photometric V results of AC And are presented schematically (dots) in Figure 1. Table 3 (available in the electronic version) gives in Column 1, the V magnitude; in Columns 2, 3 and 4 the color indexes $b-y$, m_1, and c_1; Column 5 gives the time (HJD minus 2451000) for the *uvby* system, Column 6 the β index, and Column 7 the time when this last index was measured. As can be seen, the difference between both times is very small. (To avoid noise due to interpolation the

TABLE 2

LINEAR COEFFICIENTS FOR THE STANDARD STARS VERSUS VALUES FROM THE LITERATURE

	A	B	R	N
V	−0.040	1.006	0.998	37
$b-y$	0.015	0.940	0.992	37
m_1	−0.006	1.065	0.988	38
c_1	0.003	0.984	0.995	38

HJD's of the Hβ values will be assumed to be the same as those of the *uvby* values). In order to have representative numerical values, histograms for each quantity were constructed and the Gaussian fit was evaluated; the values are presented in Table 4; also shown are the reddening-free indexes $[m_1]$, $[c_1]$, (calculated from the means) which are defined as $[m_1] = m_1 - 0.32(b-y)$ and $[c_1] = c_1 + 0.2(b-y)$.

3. REDDENING DETERMINATION

Since the correction for interstellar reddening is needed before a direct comparison with the theoretical models can be made, the determination of the reddening of AC And was undertaken. Since at this stage it has not yet been determined which type of star AC And is, we will consider it to possibly be either a δ Scuti or an RR Lyrae star. For the first step, the reddening was determined directly from the $uvby-\beta$ photometry. Then, these results were complemented with the methods employed for determining the reddening of RR Lyrae stars.

3.1. *Reddening for ms Stars from $uvby - \beta$ Photometry*

Reddening, absolute magnitude and distance modulus were determined through the mathematical expressions proposed by Nissen (1988, his equations 3, 4, and 10), which can be used to calculate the intrinsic color index $(b-y)_0$. The absolute magnitude is then calculated for F type stars and A type stars whereas the metallicity (Nissen 1988, his Eqs. 6, 7, and 8) is determined only when the star is in its *F* stage. The results of using the above mentioned prescriptions are listed in Table 5 (available in the electronic version); Column 1 is the HJD of the *uvby* system, and the following columns list the reddening $E(b-y)$, the values for the unreddened $(b-y)_0$, the m_0, the c_0, the β, the V_0, and finally, the metallicity for those stages when the star is an F star. These data are unique because, as has been stated, phasing is not required and the data provide for the possibility of calculating the physical variations of a multiple periodic star as a function of time. Mean values are presented at the end of Table 5. However, more representative values would be obtained if we considered only the two consecutive nights (87 and 88) which, when calculated in phase, would describe the whole cycle; in this case the photometric values were considered only between the phases 0.3 and 0.75 as proposed by McNamara (1997a) for excluding the zones of maximum activity of a pulsating star. Means calculated in this fashion are also shown at the end of Table 5.

If we assume AC And to be a δ Scuti star, we are implicitly assuming the star to be closer to the main sequence. In this case the applicability of Nissen's expressions (Eqs. 9, 10, 11, and 12) can be considered as valid, and hence we might be able to directly compute the M_v values with the following evaluations: the mean value of the whole season (-0.388 ± 0.565 mag) can be calculated and differs from the value of -0.374 ± 0.524 mag for the nights of 87 and 88 and of -0.331 ± 0.515 mag if only the points between the phases 0.3 and 0.75 are included on these two nights although, given the large amplitude of variation of the star, these values can be considered essentially the same. McNamara (1997a) proposes an empirical PL relation for δ Scuti stars, namely $M_v = -3.725 \log P - 1.990$ which, for the period already confirmed of $P = 0.711$ d, gives $M_v = 1.438$ mag. All these results are presented in Table 6.

3.2. *Reddening Assuming AC And to be an RR Lyrae Star*

In order to verify the reddening value, several other methods were utilized. A second procedure for the obtention of $E(B-V)$ was accomplished by merely considering the reddening for six RR Lyrae stars of galactic coordinates close to those of AC And which were taken from a work by Burstein & Heiles (1978). The mean $E(B-V)$ value obtained is of 0.050 ± 0.025 mag, although it should be kept in mind that this method gives poor results and merely serves as a rough estimate of the values one might expect.

The third approach for determining the reddening value of AC And was through the well-known formula of van Herk (1965). In view of the uncertainty in the nature of the star, we opted for using most of the available methods, although the latter method is poor and less weight should be given to its output. However, the results of all methods, as

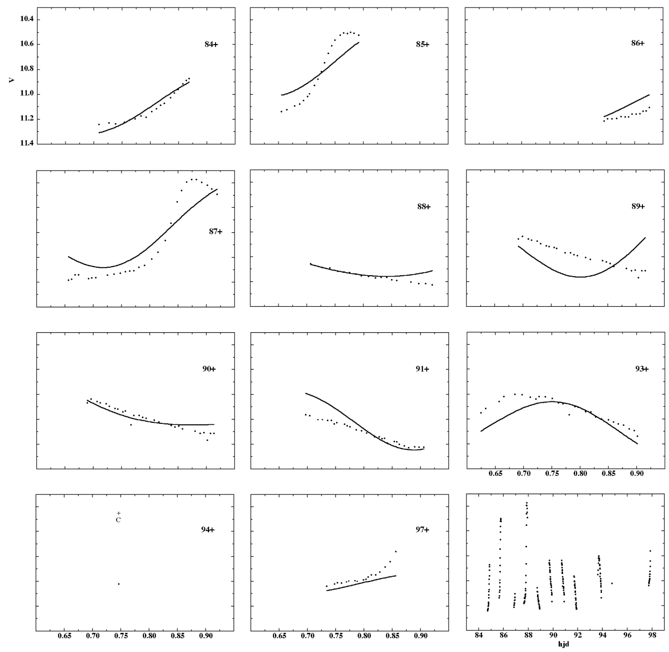

Fig. 1. Light curves of the photometric data (dots) in V. The continuous lines are the predictions with the elements reported in Table 9.

TABLE 4

REPRESENTATIVE VALUES OF THE MAGNITUDE V AND THE COLOR INDEXES

Star	$\langle V\rangle$	$\langle b-y\rangle$	$\langle m_1\rangle$	$\langle c_1\rangle$	$N_{\rm obs}$	Hβ	$N_{\rm obs}$	$\langle[m_1]\rangle$	$\langle[m_1]\rangle$
AC And	11.058	0.403	0.162	0.777	222	2.666	222	0.291	0.696

will be seen, are very similar. The van Herk formula is

$$E(B-V) = [0.0463\mathrm{cosec}|b|][1-\exp(-0.01 d \sin|b|)] \quad (1)$$

As can be seen, the extinction can be calculated if the coordinates and the distance, d, are known. For AC And, $l = 1060$ and $b = -110$; and the distance (d) can be calculated by different methods. We now attempt to calculate the distance by first evaluating the absolute magnitude of AC And.

3.3. *Calculation for M_v*

This can be done by first assuming that AC And is an RR Lyrae star; then the relation as a function of the metallicity proposed by McNamara (1997b) $M_v = 0.287$ [Fe/H]+0.964 can be employed. If, on the other hand, we assume AC And to be on or near the main sequence a value of [Fe/H]= 0.464 is obtained from the calibrations of Nissen (1988). Then, the previously mentioned calibration gives 1.097 mag. We could also use the period-dependent relation, 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, in Carreta et al. (2000; $M_v(RR) = 0.18([\mathrm{Fe/H}] + 1.5) + 0.73$), in Gratton et al. (1997; $M_v(RR) = (0.22([\mathrm{Fe/H}] + 1.5) + 0.43)$ and in Groenewegen & Salaris (1999; $M_v = 0.18[\mathrm{Fe/H}] + 0.77$) which is based on the Hipparcos parallaxes.

The distance was evaluated in the customary way, iteratively, originally assuming an $E(B-V)$ equal to zero and considering a mean apparent visual magnitude (10.995±0.192 mag). This was modified by only one iteration in which equation 1 was utilized. The extinction relation between the two photometric systems was $E(b-y) = 0.72E(B-V)$. The results are presented in Table 7. However, if adequate calibrations for RR Lyrae stars are utilized (Arellano Ferro) and considering only the data from the nights 87 and 88 which provide reasonable and typical behavior of a RR Lyrae star, and the ephemeris of Kholopov (1985) we obtain the following results: average magnitude of 10.877 mag, a [Fe/H] of −0.995, more typical for a RR Lyrae star, and the following physical characteristics: $T_{\rm e}$ of 6600 K, M_v of 0.85, and a distance modulus of 9.96 mag.

As can be seen, independently of the method, the reddening values yield two groups of numerical values not very discordant from one another: those obtained from the assumption of the δ Scuti nature, around 0.125 and those supposing the star to be an RR Lyrae star, at 0.189.

4. PHYSICAL PARAMETERS

4.1. *Metal Content of AC And Assuming it to be a δ Scuti Star*

The first procedure we have employed in the determination of the metal content of the star is based on Nissen's (1988) use of the $uvby-\beta$ photometric system data for determining accurate values of the three atmospheric parameters $T_{\rm eff}$, g, and [Fe/H] of the F and early G−type stars. The procedure followed is based on that of Nissen's (1988), Eqs. 6, 7, and 8 which give the expression $[{\rm Fe/H}] = -(10.5 + 50(\beta - 2.626))\delta m_0 + 0.12$, valid for main sequence stars in the range $2.59 < \beta < 2.72$.

As can be seen, the metallicity procedure followed was derived for main sequence stars, which would be the case if the star were a δ Scuti but questionable if AC And were an RR Lyrae star. However, in the same season in which AC And was observed, another RR Lyrae star was observed: AT And. The same procedure employed in the case of AC And were a δ Scuti star was utilized for AT And. The mean determined [Fe/H] value for AT And (Peña & Peniche 2004) was -1.08 ± 0.10. To corroborate this value, Preston's (1959) value of ΔS was considered. For AT And he lists five spectral classifications for phases between 0.01 and 0.55. By considering the well−known relation of $\Delta S = 10[{\rm Sp(H)} - {\rm Sp(Ca\,II)}]$ for spectral types at minimum light he reports a ΔS value of 3 for AT And. This value (Suntzeff, Kraft, & Kinman 1994) is transformed for RRab stars through $[{\rm Fe/H}] = -0.158\Delta S - 0.408$ to a value of -0.882 (within the uncertainties given close to that obtained in the present paper). Hence, the numerical value obtained for the metallicity of AC And is not characteristic of an RR Lyrae star but of a Pop I star whereas that obtained for AT And, is. Another difference between δ Scuti and RR Lyrae stars is the presence of stable modes of pulsation.

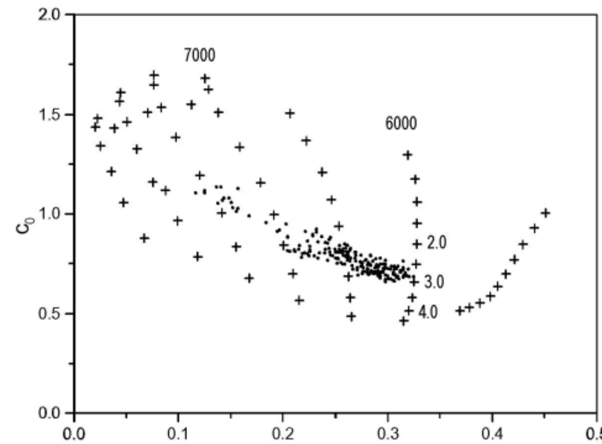

Fig. 2. Unreddened values of $b-y$ and c_0 to obtain $\log T_{\rm e}$ and $\log g$ on the theoretical grids.

Furthermore, in a similar study of RR Lyrae stars covering the evaluation of the physical characteristics of some selected stars in Serpens from Strömgren photometry, the usage of the same calibration described by Nissen (1988) for main sequence stars gave negative values for the RR Lyrae stars in Serpens [Fe/H] except for AC And; If the previous assumptions prove to be correct, one might conclude that AC And may be of anomalous chemical composition. These [Fe/H] when compared (Peña 2003), for example with AN Ser for which spectroscopic data are available and Preston's ΔS index can be determined, gave an adequate correlation, establishing the applicability Nissen's method extended to the stars in the RR Lyrae branch, although this assertion requieres corroboration.

For AC And, the mean [Fe/H] and the standard deviation of the whole data set at all phases assuming the calibrations of Nissen (1988) for main sequence stars are 0.46 ± 0.18, and the distance modulus is 10.83 ± 0.59 mag. These values remain basically the same if we consider the whole sample or just those values between the phases $0.3 \rightarrow 0.75$. This result is quite obvious since the majority of the data points acquired lie in the times of minimum light with few at times of maximum light, a phase through which the stars pass rapidly. Other physical quantities, like $\log T_{\rm e}$ and $\log g$, depend on the intrinsic colors of the star throughout the cycle.

The determination of the effective temperature and surface gravity can be made from the intrinsic mean color indexes already presented. The unreddened values of the star $b-y$ and c_1 are used to obtain $\log T_{\rm e}$ and $\log g$ by positioning these indexes in the output of theoretical models in the grids of

TABLE 6

ABSOLUTE MAGNITUDE AND REDDENING VALUES OF AC AND ASSUMING IT TO BE A δ SCUTI STAR

M_v	Distance	$E(b-y)$	Method	Remarks
−0.388	1520	0.128	*uvby*	From Nissen, whole sample
−0.331	1520	0.125	*uvby*	From Nissen, only 87 − 88
···	···	···	···	In phase 0.3 − 0.75
−1.382	638	0.157	PL	McNamara (1997a)
3.183	335	0.120	*uvby*, Hipparcos	···

TABLE 7

ABSOLUTE MAGNITUDE & REDDENING VALUES OF AC AND ASSUMING IT TO BE AN RR LYRAE STAR

M_v	Distance	$E(b-y)$	Method	Remarks
−1.360	2960	0.153	Van Herck	Hipparcos
···	···	0.036	Statistic	Mean of zone
0.678	1590	0.190	Metalicity	McNamara (1997b)
0.622	1550	0.190	Metalicity	McNamara (2001)
0.541	1180	0.185	Metalicity	Grattton97
0.591	1500	0.189	Metalicity	G&S99
0.821	1700	0.191	Metalicity	Carreta
0.850	2220	···	Fourier analysis	Arellano Ferro et al.

Lester, Gray, & Kurucz (1986). In Figure 2, we plot the $b-y$ and c_1 unreddened indexes of AC And and find that $T_{\rm eff}$ varies within the range 6000 K to 7500 K and $\log g$ around 3.0 for the metallicity found assuming it to be a δ Scuti star.

4.2. *Metal Content of AC And assuming it to be an RR Lyrae Star by Fourier Decomposition of the Light Curve*

As an alternative method, assuming this time AC And is an RR Lyrae star, we have used the technique of Fourier decomposition of the light curve to estimate some of the physical parameters of the star (Arellano Ferro et al. 2004). Under this approach, the light curve is represented by a series of harmonics of the form:

$$f(t) = A_0 + \sum_{k=1}^{n} A_k cos(2\pi k(t-E)/P + \phi_k), \quad (2)$$

From the amplitudes and phases of the harmonics in the above equation, calculated assuming the ephemerides of Kholopov (1985) for the nights of 87 and 88, in which they describe basically a whole cycle, the Fourier parameters were calculated as (A_0, A_1, ϕ_{21}, ϕ_{31}, ϕ_{41}) as (10.8767, 0.3428, 4.0952, 1.97039, 5.59659). Simon & Clement (1993) first offered calibrations of the effective temperature $T_{\rm eff}$, a helium content parameter Y, the stellar mass M and the luminosity $\log L$, in terms of the period and Fourier parameter ϕ_{31} for RRc type RR Lyrae. Their work was extended to RRab stars by Jurcsik & Kovács (1996), Kovács & Jurcsik (1996; 1997), and Jurcsik (1998). The specific equations can be found in these papers, while a thorough discussion of the uncertainties in the physical parameters, as obtained from the above mentioned calibrations, can be found in the work of Jurcsik (1998). We have then estimated the physical parameters of AC And using these calibrations. The results are reported in Table 8.

The temperature determination, assuming the star an RR Lyrae star, might be obtained from the numerical relations found empirically by McNamara (1997b) who gives $\langle T_{\rm eff}\rangle = -1039 \log P + 6467$ and

$\langle T_{\rm eff}\rangle$ = 108 [Fe/H] + 6874. In these cases, once the period and the metallicity have been found, the corresponding $\langle T_{\rm eff}\rangle$ values are 6621 K and 6770 K, respectively. The temperature value of was found when AC And is assumed an RR Lyrae with a [Fe/H] −0.995. The mean of these temperature values is 6700 K ($\log T_{\rm e} = 3.830$).

5. PERIODIC CONTENT OF AC AND

Since one of the most important characteristics needed to define the nature of a variable star is the determination of its periodic content, it is necessary to confirm, as K&B 94 suggested, the periodic content of AC And. The first reliable periods were proposed by F&S 76 ($P_0 = 0^d.71124243$, $P_1 = 0^d.52512677$, and $P_2 = 0^d.4211069$) and they have remained undisputed since then. It would be interesting, as K&B 94 suggested, to study the periodicity of pulsation of this star with more data. Hence, a period analysis was carried out using all the available data to determine the frequencies and to verify their constancy.

The period determination analysis was carried out using the method developed by Breger (PERIOD, 1991) that can fit and improve the multiple frequencies simultaneously without prewhitening and results in best values for the frequencies, amplitudes, phases, and zero−points. We approached the period analysis in the following way: the data from Guman (1982), which were employed for the analysis (since not all his data set was considered), were partitioned in four subsets to avoid the complications of aliasing in the window function introduced by the enormous gaps between the years of observations. Furthermore, nights with a very short time coverage, (time spans of less than two hours) were not included. A summary of the data Guman (1982) that is used is presented in Table 9, which also includes other data from papers by Notni (1963), Jakate (1978), and from the present study divided in two sets, PP 92 and PP 98.

The analysis for each season gives the results presented in Table 10. As we can see, most of the frequencies lie in the main regions: at $0.5, 1.4, 1.8, 2.3, 2.9$, and only two beyond the 4.0 c/d value. What has been considered as canonical are the values of F&S 76 namely, 1.40607, 1.90433, and 2.37491 c/d. Evidently, there are many aliasing problems with the analyzed data. If we plot the output in frequency intervals an immediate question arises, might there be an aliasing problem between the 0.5 and 1.4 values? and at frequency values at around 1.9 and 2.9 c/d? And if so, which value is correct? These possibilities led to a thorough analysis of the data considering not only the periodograms output but the their time span, the coverage as well as the maxima in each data set.

For a numerical evaluation of the final conclusion we did the following: first, we assumed the frequencies reported by F&S 76 to be correct and fitted the data evaluating the residuals as numerical discriminators. Then, we assumed that those values that might be aliases to be such, and modified them by the 1 c/d value; then the mean average was calculated and each data set was analyzed with these mean values as input and fitted with the ad hoc option. Those mean values were: 0.4724, 1.8797, and 2.3729 c/d. The residuals were calculated and are presented in Table 11. The results confirm the validity of the values presented by F&S 76, and predictions using these results are compared with the observations in Fig. 1. This was one of the points suggested by K&B 94; however, we mention that, although the phasing is adequate, the fine details of the light curves are not properly described by this set of frequencies, amplitudes and phases.

6. DISCUSSION

Now, what is the status of AC And? This star has been the subject of numerous studies that at times establish it, with valid reasons, either as a δ Scuti star or as an RR Lyrae star. Its true nature should be unequivocally determined by establishing its periodic contents as well as by fixing its position in the H−R diagram, or from its physical parameters determined through comparisons of the observed photometric values with theoretical models.

As we can see from Tables 6 and 7, the question of the nature of AC And is not yet solved, particularly because some of the values were calculated previously assuming the nature of the star. In this category lie those empirical relations developed specifically for either RR Lyrae or δ Scuti stars. The values from the Strömgren $uvby-\beta$ photometry have been tested only for main sequence stars.

The absolute magnitude can be determined, though, as was mentioned in section three, from numerous empirical calibrations. However, the obtained results cannot serve to discriminate its nature because we would be using a recursive argument: assuming its nature to verify the result. There are proposals such as that of Fernie (1994), which is based on a global behavior of the pulsating variables. He plots a period-luminosity relation in his Fig. 1 for δ Scuti stars and Cepheids in open clusters and, from the linearity shown, he speculates that AC And fits

TABLE 8

PHYSICAL PARAMETERS OF AC DERIVED FROM FOURIER DESCOMPOSITION ASSUMING IT TO BE AN RR LYRAE STAR

[Fe/H]	$T_{\rm e}$	M_v	$\log L/L_{\odot}$	DM	$\log T_{\rm e}$
−0.995	6600	0.851	1.560	9.962	3.820

TABLE 9

SUMMARY OF THE PHOTOMETRIC DATA USED FOR PERIOD ANALYSIS

Set	Source	$T_{\rm i}$ (days)	T_f (days)	ΔT (days)	No nights	No points
33000	Guman 82	33452	33569	117	18	1074
34000	Guman 82	33583	33982	399	9	451
34250	Guman 82	34192	34305	113	13	746
34500	Guman 82	34567	34664	97	15	774
Sum82	Guman 82	33452	34664	1112	45	3045
36800	Notni 63	36813	36826	13	8	141
42697	Jakate 78	42697	42707	10	7	168
48884	PP 92	48884	48897	13	10	221
51088	PP 98	51087	51089	3	3	181

Time (shown) = HJD-2400000.0.

the trend if it is assumed to be a 3 $M_{\odot}$ star. He asserts that the agreement is fortuitously good, but he later specifies that the mass of AC And was only estimated at about 3 $M_{\odot}$, and that small changes in the correlation would entail systematic changes in any absolute magnitude determination. He concludes that there are strong indications that AC And indeed bridges the gap between δ Scuti stars and classical Cepheids.

For the sake of discussion, we might consider Fernie's (1994) point of view. We now know that the period (or period set) is indisputable. Hence, the location of AC And in the X−axis in Fig. 1 of Fernie (1994) is correct, but is AC And then a 3 solar mass star? If Fernie's (1994) point of view that AC And indeed bridges the gap between δ Scuti stars and classical Cepheids is correct, there would be no discussion. However, if we consider that AC And might be an RR Lyrae star, we would have to look at where the rest of the RR Lyrae stars would lie on this diagram. To fill the gap we might consider a sample of these stars provided by McNamara (1997b). If we take his data into account for the absolute magnitudes of such stars, as well as their periods, and position them in Fernie's (1994) Fig. 1 they do not lie on the line joining δ Scuti stars and Cepheids, but on a parallel line, one magnitude lower. Therefore, the absolute magnitude of AC And has to lie between these two values at about −0.7, if that is what Fernie (1994) proposes, and at +0.5 mag if it is a RR Lyrae star.

What we can see from Tables 6 and 7, a compilation of the absolute magnitude values calculated in this work, is that one cannot assume a nature of the star to derive the corresponding absolute magnitude and discriminate its nature so, a different approach has to be faced.

To begin with, we can try to determine, through evolutive tracks, if AC And is indeed a 3 $M_{\odot}$ star. From the determined temperature, fixed independently if it is a δ Scuti or a RR Lyrae star, and from the absolute magnitude values which, although quite different for either case, no significative difference is found in tracks such like those of Schaerer et al. (1993) in which, the location of AC And is around 1.7 to 2.0 $M_{\odot}$. Hence, Fernie's (1994) assumption on the mass is not fulfilled.

A different approach to determining its nature has to be found. As Fernie (1994) himself suggests, and as was stated in the introduction, it would be extremely useful to have new photometry, carried out in "the Strömgren or Geneva systems", that would provide checks on the metallicity, luminosity, temperature, etc. of AC And. This same proposal was suggested by K&B 94 who, unable to reach a definite conclusion from the available data at that time, encouraged the obtention of multicolor photometry to improve the knowledge of the chemical composition, temperature, and luminosity. In view of these suggestions, and having at disposition the requested multicolor photometry, what we have done is to determine the physical characteristics of AC And by locating it in the theoretical outputs of Lester et al. (1986) which was presented in Fig. 2.

If AC And is of a δ Scuti nature, its physical values should be similar to those of large amplitude δ Scuti stars. There are several of these stars, the most important of which, CY Aqr, DY Her, DY Peg, and YZ Boo, have been measured in multicolor Strömgren photometry (Peña, González, & Peniche 1999). The location of the obtained results for their corresponding chemical compositions in the $(b-y)_0$ vs. c_0 diagrams of Lester et al. (1986) fixes them at temperature ranges from 7000 K to 8000 K and $\log g$ values of 4.0.

It would be interesting to compare the location of AC And in the above mentioned diagrams. As we have seen previously, its chemical composition has not been unquestionably determined because its value depends on the assumed nature of the star. Values of [Fe/H] of 0.5 and -1.0 were determined assuming it was either a main sequence stars or an RR Lyrae star but, in both cases, its temperature range variation is at cooler temperatures from 6000 K or 5750 K, respectively up to 7500 K. More importantly, the $\log g$ value determined from the location of AC And along the cycle is 3.0 or 2.5 depending on the metallicity value considered but, in any case, with values typical of a more evolved star than those found for any of the large amplitude δ Scuti stars.

In view of this we conclude that AC And is NOT a large amplitude δ Scuti star but an RR Lyrae star, but it is atypical because it has already been proved that it is multi-periodic. Its peculiarity is a fact that was stated in the literature long ago.

7. CONCLUSIONS

We have presented new observations, both differential and multicolor Strömgren photometry, of this star. We have carried out a period analysis and conclude that the correct set of frequencies is that proposed by F&S 76; we have tried to determined the metallicity, the reddening and the distance to the star; and the physical parameters $\log g$ and $\log T_{\rm e}$ have been evaluated. Finally, we have used indirect methods to determine the nature of the star and conclude that it most likely is an RR Lyrae star. In conclusion, we have satisfied the request for data by the theoreticians (K&B 94, Fernie (1994)) but still there are ambiguities in its periodic content because, although adequate the fitting, still misses some exactness; certainly, a better determination of the metal content through spectroscopic studies, is needed.

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TABLE 1

DIFFERENTIAL *V* PHOTOELECTRIC PHOTOMETRY OF AC AND

Time	ΔV	Time	ΔV	Time	ΔV	Time	ΔV	Time	ΔV
87.633	−1.175	87.791	−.595	88.659	−1.202	88.824	−1.195	89.756	−1.105
87.636	−1.179	87.793	−.603	88.662	−1.180	88.827	−1.177	89.763	−1.102
87.638	−1.132	87.797	−.602	88.666	−1.190	88.833	−1.180	89.768	−1.077
87.641	−1.120	87.800	−.614	88.669	−1.185	88.837	−1.137	89.775	−1.073
87.644	−1.143	87.803	−.626	88.674	−1.164	88.843	−1.113	89.779	−1.081
87.647	−1.135	87.805	−.612	88.678	−1.179	88.849	−1.158	89.783	−1.074
87.649	−1.078	87.809	−.620	88.682	−1.167	88.853	−1.155	89.786	−1.053
87.653	−1.074	87.812	−.622	88.685	−1.201	88.856	−1.113	89.790	−1.029
87.656	−1.074	87.816	−.643	88.690	−1.210	88.864	−1.103	89.793	−1.048
87.661	−1.055	87.819	−.664	88.693	−1.214	88.872	−1.092	89.797	−.941
87.667	−1.053	87.823	−.674	88.699	−1.245	88.877	−1.096	89.802	−.947
87.677	−1.012	87.826	−.674	88.705	−1.191	88.884	−1.111	89.806	−.904
87.681	−.961	87.829	−.689	88.711	−1.202	88.887	−1.107	89.810	−.906
87.691	−1.029	87.832	−.717	88.718	−1.191	88.891	−1.130	89.813	−.878
87.695	−.884	87.836	−.739	88.725	−1.212	88.894	−1.061	89.815	−.862
87.699	−.845	87.839	−.720	88.730	−1.199	88.898	−1.099	89.819	−.825
87.704	−.813	87.843	−.727	88.738	−1.215	89.642	−1.311	89.823	−.822
87.709	−.779	87.846	−.723	88.742	−1.207	89.650	−1.357	89.827	−.762
87.713	−.755	87.849	−.751	88.751	−1.190	89.656	−1.302	89.837	−.691
87.719	−.735	87.852	−.774	88.755	−1.266	89.670	−1.335	89.843	−.655
87.730	−.640	87.856	−.807	88.760	−1.239	89.674	−1.329	89.848	−.650
87.738	−.600	87.859	−.767	88.763	−1.243	89.677	−1.319	89.851	−.641
87.742	−.601	87.863	−.813	88.769	−1.248	89.681	−1.371	89.854	−.620
87.747	−.598	87.866	−.785	88.772	−1.227	89.685	−1.291	89.858	−.617
87.751	−.588	87.870	−.842	88.778	−1.224	89.690	−1.275	89.861	−.656
87.754	−.583	87.873	−.816	88.784	−1.197	89.694	−1.220	89.872	−.592
87.758	−.580	87.876	−.885	88.789	−1.195	89.701	−1.214	89.876	−.582
87.761	−.562	87.879	−.825	88.792	−1.242	89.705	−1.233	89.878	−.566
87.766	−.564	87.883	−.888	88.797	−1.202	89.716	−1.197	89.885	−.555
87.768	−.565	87.886	−.826	88.800	−1.199	89.722	−1.160	89.890	−.580
87.772	−.566	87.890	−.867	88.805	−1.210	89.727	−1.172	89.897	−.576
87.775	−.580	87.892	−.886	88.807	−1.209	89.732	−1.178	89.900	−.580
87.778	−.579	87.896	−.901	88.811	−1.197	89.736	−1.160	89.903	−.574
87.781	−.582	88.645	−1.183	88.814	−1.182	89.742	−1.181	89.906	−.581
87.784	−.586	88.651	−1.178	88.817	−1.185	89.746	−1.150	89.910	−.594
87.787	−.587	88.655	−1.194	88.820	−1.201	89.752	−1.153	89.913	−.603

Time (shown) = HJD-2400000.0.

TABLE 3

$uvby-\beta$ PHOTOELECTRIC PHOTOMETRY OF AC AND

V	$b-y$	m_1	c_1	HJD($uvby$)	β	HJD(β)
11.241	0.443	0.164	0.744	84.7091	2.652	84.7101
11.228	0.440	0.161	0.740	84.7269	2.658	84.7279
11.236	0.435	0.150	0.747	84.7381	2.655	84.7390
11.224	0.423	0.180	0.733	84.7539	2.675	84.7549
11.206	0.431	0.155	0.745	84.7626	2.643	84.7635
11.196	0.420	0.179	0.722	84.7726	2.662	84.7736
11.173	0.435	0.142	0.763	84.7834	2.658	84.7843
11.183	0.410	0.165	0.779	84.7920	2.683	84.7933
11.139	0.421	0.134	0.802	84.8025	2.663	84.8042
11.115	0.417	0.142	0.799	84.8104	2.696	84.8115
11.087	0.412	0.134	0.819	84.8180	2.653	84.8189
11.074	0.397	0.147	0.832	84.8243	2.706	84.8252
11.027	0.388	0.152	0.851	84.8355	2.715	84.8364
10.988	0.381	0.171	0.832	84.8420	2.667	84.8429
10.960	0.372	0.141	0.897	84.8488	2.695	84.8496
10.913	0.374	0.133	0.905	84.8573	2.710	84.8640
10.885	0.357	0.157	0.921	84.8633	2.709	84.8693
10.870	0.350	0.147	0.935	84.8685	2.734	84.8759
11.138	0.394	0.188	0.766	85.6554	2.673	85.6562
11.123	0.409	0.167	0.746	85.6646	2.672	85.6655
11.093	0.385	0.194	0.771	85.6782	2.683	85.6791
11.078	0.381	0.172	0.799	85.6871	2.664	85.6880
11.050	0.379	0.180	0.802	85.6942	2.696	85.6953
11.016	0.376	0.170	0.814	85.7013	2.689	85.7022
10.994	0.373	0.164	0.833	85.7047	2.695	85.7055
10.927	0.369	0.155	0.846	85.7135	2.704	85.7144
10.875	0.354	0.169	0.863	85.7194	2.710	85.7203
10.817	0.333	0.172	0.905	85.7255	2.712	85.7264
10.746	0.323	0.172	0.936	85.7311	2.720	85.7321
10.670	0.312	0.162	0.980	85.7375	2.742	85.7384
10.609	0.296	0.165	1.014	85.7440	2.738	85.7448
10.560	0.285	0.163	1.052	85.7497	2.753	85.7506
10.521	0.280	0.168	1.054	85.7586	2.765	85.7596
10.503	0.280	0.168	1.055	85.7652	2.768	85.7660
10.508	0.270	0.159	1.094	85.7714	2.753	85.7724
10.499	0.279	0.152	1.082	85.7773	2.765	85.7783
10.505	0.272	0.158	1.103	85.7833	2.770	85.7843
10.521	0.277	0.157	1.105	85.7916	2.755	85.7926
11.214	0.443	0.171	0.788	86.8452	2.647	86.8460
11.196	0.426	0.183	0.682	86.8517	2.649	86.8611
11.196	0.431	0.172	0.699	86.8595	2.665	86.8690

TABLE 3 (CONTINUED)

V	$b-y$	m_1	c_1	HJD($uvby$)	β	HJD(β)
11.193	0.421	0.181	0.715	86.8680	2.658	86.8764
11.178	0.429	0.173	0.700	86.8753	2.659	86.8834
11.181	0.421	0.169	0.728	86.8824	2.667	86.8899
11.180	0.419	0.177	0.714	86.8889	2.643	86.8959
11.158	0.426	0.155	0.759	86.8950	2.652	86.9033
11.158	0.404	0.186	0.723	86.9023	2.660	86.9095
11.156	0.405	0.181	0.736	86.9086	2.696	86.9153
11.136	0.409	0.172	0.750	86.9144	2.663	86.9208
11.132	0.404	0.164	0.763	86.9199	2.660	86.9263
11.106	0.409	0.159	0.768	86.9252	2.660	86.9315
11.183	0.409	0.193	0.744	87.6561	2.651	87.6553
11.177	0.417	0.183	0.753	87.6620	2.655	87.6629
11.141	0.424	0.172	0.731	87.6679	2.658	87.6686
11.140	0.435	0.170	0.689	87.6739	2.635	87.6746
11.172	0.410	0.193	0.721	87.6917	2.647	87.6926
11.165	0.421	0.182	0.704	87.6975	2.641	87.6984
11.163	0.409	0.182	0.730	87.7045	2.658	87.7055
11.143	0.420	0.164	0.732	87.7249	2.662	87.7242
11.136	0.406	0.177	0.736	87.7367	2.668	87.7360
11.129	0.404	0.177	0.727	87.7478	2.658	87.7470
11.116	0.400	0.189	0.718	87.7564	2.652	87.7556
11.111	0.399	0.181	0.744	87.7645	2.646	87.7636
11.109	0.399	0.175	0.756	87.7718	2.639	87.7731
11.081	0.412	0.148	0.766	87.7807	2.676	87.7816
11.066	0.395	0.163	0.746	87.7905	2.689	87.7915
11.014	0.393	0.149	0.802	87.8030	2.692	87.8039
10.956	0.368	0.158	0.828	87.8145	2.697	87.8120
10.864	0.340	0.185	0.837	87.8273	2.673	87.8155
10.725	0.325	0.148	0.944	87.8370	2.704	87.8282
10.552	0.284	0.159	1.037	87.8481	2.715	87.8360
10.461	0.266	0.161	1.076	87.8558	2.737	87.8473
10.391	0.245	0.171	1.129	87.8650	2.781	87.8566
10.373	0.253	0.156	1.129	87.8735	2.762	87.8641
10.372	0.253	0.156	1.140	87.8819	2.762	87.8727
10.394	0.253	0.156	1.142	87.8914	2.773	87.8810
10.418	0.265	0.141	1.158	87.9012	2.773	87.8905
10.447	0.269	0.135	1.158	87.9095	2.771	87.9002
10.490	0.285	0.126	1.151	87.9190	2.757	87.9103
11.057	0.408	0.165	0.794	88.7067	2.684	88.7060
11.089	0.403	0.181	0.780	88.7272	2.643	88.7265
11.091	0.424	0.153	0.771	88.7408	2.664	88.7400
11.116	0.417	0.175	0.729	88.7537	2.652	88.7529

TABLE 3 (CONTINUED)

V	$b-y$	m_1	c_1	HJD($uvby$)	β	HJD(β)
11.123	0.424	0.165	0.750	88.7653	2.660	88.7645
11.127	0.428	0.163	0.749	88.7756	2.663	88.7748
11.142	0.422	0.181	0.733	88.7865	2.669	88.7856
11.152	0.420	0.188	0.712	88.7964	2.651	88.7972
11.158	0.434	0.163	0.721	88.8090	2.685	88.8080
11.170	0.426	0.185	0.718	88.8212	2.658	88.8203
11.166	0.434	0.168	0.724	88.8308	2.662	88.8300
11.165	0.448	0.143	0.748	88.8412	2.647	88.8403
11.185	0.428	0.186	0.715	88.8499	2.633	88.8491
11.192	0.433	0.187	0.691	88.8586	2.653	88.8594
11.203	0.440	0.160	0.732	88.8840	2.648	88.8697
11.216	0.438	0.176	0.709	88.8979	2.668	88.8829
11.216	0.434	0.172	0.731	88.9097	2.672	88.8974
11.226	0.441	0.160	0.734	88.9217	2.673	88.9087
10.855	0.360	0.161	0.934	89.6920	2.701	89.6914
10.835	0.357	0.157	0.923	89.6991	2.720	89.6985
10.857	0.357	0.162	0.915	89.7093	2.699	89.7087
10.865	0.365	0.148	0.910	89.7150	2.706	89.7140
10.874	0.387	0.136	0.875	89.7254	2.668	89.7247
10.894	0.369	0.160	0.879	89.7311	2.670	89.7302
10.910	0.372	0.164	0.850	89.7410	2.680	89.7401
10.917	0.382	0.140	0.867	89.7461	2.672	89.7455
10.924	0.385	0.157	0.840	89.7550	2.668	89.7544
10.931	0.390	0.140	0.865	89.7596	2.668	89.7687
10.967	0.398	0.141	0.832	89.7745	2.652	89.7739
10.967	0.393	0.151	0.851	89.7839	2.646	89.7848
10.981	0.390	0.167	0.820	89.7900	2.670	89.7891
10.990	0.391	0.168	0.812	89.7961	2.685	89.7952
11.007	0.403	0.151	0.817	89.8103	2.665	89.8093
11.022	0.398	0.160	0.819	89.8189	2.647	89.8180
11.032	0.412	0.157	0.769	89.8406	2.680	89.8468
11.043	0.420	0.148	0.760	89.8474	2.672	89.8530
11.056	0.418	0.158	0.769	89.8536	2.647	89.8599
11.077	0.416	0.173	0.735	89.8605	2.669	89.8679
11.095	0.415	0.179	0.725	89.8827	2.654	89.8818
11.114	0.419	0.162	0.738	89.8913	2.664	89.8906
11.108	0.416	0.176	0.753	89.8982	2.673	89.8976
11.167	0.405	0.167	0.756	89.9041	2.660	89.9033
11.114	0.425	0.171	0.745	89.9099	2.641	89.9093
11.114	0.437	0.146	0.750	89.9157	2.670	89.9151
10.867	0.360	0.167	0.949	90.6894	2.701	90.6887
10.835	0.357	0.157	0.923	90.6964	2.720	90.6957

TABLE 3 (CONTINUED)

V	$b-y$	m_1	c_1	HJD($uvby$)	β	HJD(β)
10.857	0.357	0.162	0.915	90.7066	2.699	90.7059
10.865	0.365	0.148	0.910	90.7123	2.706	90.7113
10.874	0.387	0.136	0.875	90.7226	2.668	90.7220
10.894	0.369	0.160	0.879	90.7284	2.670	90.7275
10.910	0.372	0.164	0.850	90.7382	2.680	90.7374
10.917	0.382	0.140	0.867	90.7434	2.672	90.7428
10.939	0.378	0.168	0.846	90.7523	2.668	90.7517
10.931	0.390	0.140	0.865	90.7569	2.668	90.7660
11.046	0.391	0.193	0.831	90.7667	2.652	90.7712
10.967	0.398	0.141	0.832	90.7718	2.647	90.7803
10.967	0.393	0.151	0.851	90.7812	2.653	90.7820
10.981	0.390	0.167	0.820	90.7873	2.670	90.7864
10.990	0.391	0.168	0.812	90.7933	2.685	90.7925
11.007	0.403	0.151	0.817	90.8076	2.665	90.8066
11.022	0.398	0.160	0.819	90.8162	2.647	90.8153
11.051	0.404	0.169	0.780	90.8379	2.680	90.8440
11.062	0.410	0.159	0.775	90.8447	2.672	90.8503
11.056	0.418	0.158	0.769	90.8509	2.647	90.8572
11.077	0.416	0.173	0.735	90.8578	2.669	90.8652
11.095	0.415	0.179	0.725	90.8800	2.654	90.8791
11.114	0.419	0.162	0.738	90.8886	2.664	90.8879
11.108	0.416	0.176	0.753	90.8955	2.673	90.8949
11.167	0.405	0.167	0.756	90.9014	2.660	90.9006
11.114	0.425	0.171	0.745	90.9072	2.641	90.9066
11.114	0.437	0.146	0.750	90.9130	2.670	90.9124
10.962	0.381	0.175	0.804	91.6968	2.648	91.6962
10.970	0.392	0.163	0.786	91.7039	2.669	91.7033
11.003	0.390	0.174	0.793	91.7185	2.686	91.7178
11.003	0.397	0.155	0.803	91.7264	2.654	91.7257
11.009	0.407	0.150	0.793	91.7357	2.679	91.7364
11.011	0.412	0.137	0.815	91.7425	2.675	91.7418
11.038	0.402	0.161	0.783	91.7470	2.664	91.7464
11.028	0.414	0.148	0.788	91.7514	2.674	91.7509
11.041	0.426	0.147	0.772	91.7658	2.667	91.7649
11.052	0.421	0.152	0.772	91.7702	2.657	91.7696
11.061	0.426	0.137	0.793	91.7753	2.665	91.7742
11.085	0.419	0.164	0.757	91.7859	2.647	91.7851
11.094	0.432	0.144	0.760	91.7957	2.669	91.7922
11.110	0.431	0.158	0.748	91.8047	2.652	91.8038
11.141	0.438	0.152	0.763	91.8181	2.651	91.8103
11.141	0.443	0.142	0.756	91.8269	2.646	91.8262
11.155	0.436	0.164	0.718	91.8316	2.684	91.8309

TABLE 3 (CONTINUED)

V	$b-y$	m_1	c_1	HJD($uvby$)	β	HJD(β)
11.154	0.445	0.157	0.730	91.8363	2.669	91.8357
11.191	0.426	0.191	0.694	91.8412	2.643	91.8406
11.179	0.449	0.154	0.709	91.8532	2.663	91.8525
11.182	0.453	0.155	0.708	91.8579	2.637	91.8573
11.202	0.437	0.172	0.705	91.8623	2.669	91.8617
11.214	0.443	0.162	0.706	91.8708	2.636	91.8699
11.228	0.444	0.156	0.718	91.8790	2.637	91.8781
11.222	0.439	0.177	0.697	91.8890	2.657	91.8881
11.224	0.447	0.151	0.713	91.8972	2.664	91.8963
11.224	0.444	0.161	0.713	91.9054	2.646	91.9047
10.948	0.346	0.175	0.806	93.6247	2.696	93.6241
10.914	0.347	0.175	0.826	93.6331	2.692	93.6325
10.859	0.349	0.186	0.827	93.6569	2.687	93.6563
10.819	0.335	0.173	0.836	93.6650	2.698	93.6644
10.801	0.333	0.181	0.838	93.6845	2.687	93.6839
10.802	0.339	0.171	0.843	93.6972	2.683	93.6965
10.823	0.354	0.159	0.844	93.7119	2.691	93.7109
10.838	0.344	0.149	0.865	93.7216	2.684	93.7210
10.819	0.343	0.164	0.848	93.7270	2.702	93.7262
10.821	0.352	0.165	0.823	93.7381	2.689	93.7372
10.833	0.354	0.164	0.835	93.7508	2.701	93.7501
10.869	0.358	0.170	0.814	93.7617	2.701	93.7501
10.876	0.353	0.176	0.813	93.7692	2.676	93.7609
10.964	0.362	0.186	0.801	93.7808	2.676	93.7609
10.899	0.363	0.165	0.829	93.7903	2.666	93.7685
10.903	0.374	0.158	0.816	93.7960	2.666	93.7685
10.940	0.371	0.176	0.792	93.8092	2.662	93.7895
10.941	0.387	0.172	0.771	93.8186	2.662	93.7895
10.983	0.380	0.167	0.777	93.8274	2.670	93.8083
10.997	0.384	0.170	0.782	93.8371	2.670	93.8083
11.007	0.403	0.157	0.763	93.8501	2.657	93.8267
11.024	0.399	0.174	0.744	93.8588	2.657	93.8346
11.041	0.403	0.169	0.760	93.8673	2.651	93.8387
11.050	0.411	0.173	0.729	93.8767	2.671	93.8492
11.081	0.411	0.179	0.725	93.8868	2.668	93.8578
11.092	0.414	0.171	0.731	93.8953	2.664	93.8667
11.137	0.413	0.191	0.739	93.9008	2.657	93.8776
11.021	0.398	0.150	0.786	94.7462	2.671	94.7456
11.041	0.387	0.157	0.815	97.7340	2.650	97.7346
11.021	0.385	0.153	0.828	97.7479	2.669	97.7485
11.013	0.389	0.158	0.810	97.7528	2.656	97.7539
11.014	0.374	0.165	0.818	97.7601	2.671	97.7607

TABLE 3 (CONTINUED)

V	$b-y$	m_1	c_1	HJD($uvby$)	β	HJD(β)
11.004	0.392	0.132	0.842	97.7691	2.679	97.7715
10.997	0.389	0.151	0.808	97.7730	2.697	97.7865
10.994	0.390	0.136	0.830	97.7839	2.652	97.7998
11.000	0.382	0.140	0.833	97.7879	2.685	97.8038
10.988	0.382	0.135	0.846	97.7991	2.682	97.8079
10.981	0.379	0.144	0.834	97.8031	2.687	97.8136
10.965	0.379	0.150	0.836	97.8073	2.671	97.8210
10.946	0.389	0.121	0.866	97.8130	2.691	97.8286
10.947	0.371	0.134	0.878	97.8203	2.693	97.8377
10.924	0.362	0.147	0.883	97.8279	2.696	97.8470
10.884	0.352	0.147	0.888	97.8370	2.703	97.8569
10.841	0.333	0.158	0.910	97.8461	2.703	97.8569

Time (shown) = HJD-2400000.0

TABLE 5

REDDENING, UNREDDENED COLOR INDEXES, AND METALLICITY FOR THE STAR AC AND

HJD	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	[Fe/H]
84.7091	0.144	0.299	0.207	0.715	2.652	10.620	0.475
84.7269	0.149	0.291	0.206	0.710	2.658	10.590	0.495
84.7381	0.145	0.290	0.193	0.718	2.655	10.610	0.329
84.7462	0.131	0.267	0.189	0.760	2.671	10.460	0.355
84.7539	0.149	0.274	0.225	0.703	2.675	10.580	0.823
84.7626	0.126	0.305	0.193	0.720	2.643	10.670	0.248
84.7726	0.130	0.290	0.218	0.696	2.662	10.640	0.668
84.7834	0.151	0.284	0.187	0.733	2.658	10.520	0.273
84.7920	0.153	0.257	0.211	0.748	2.683	10.530	0.662
84.8025	0.148	0.273	0.178	0.772	2.663	10.500	0.187
84.8104	0.180	0.237	0.196	0.763	2.696	10.340	0.463
84.8180	0.130	0.282	0.173	0.793	2.653	10.530	0.075
84.8243	0.173	0.224	0.199	0.797	2.706	10.330	0.494
84.8355	0.175	0.213	0.204	0.816	2.715	10.280	0.552
84.8420	0.107	0.274	0.203	0.811	2.667	10.530	0.513
84.8488	0.142	0.230	0.183	0.869	2.695	10.350	0.287
84.8573	0.161	0.213	0.181	0.873	2.710	10.220	0.227
84.8633	0.141	0.216	0.199	0.893	2.709	10.280	0.494
84.8685	0.168	0.182	0.197	0.901	2.734	10.150	···
85.6554	0.119	0.275	0.224	0.742	2.673	10.620	0.803
85.6646	0.136	0.273	0.208	0.719	2.672	10.540	0.595
85.6782	0.123	0.262	0.231	0.746	2.683	10.560	0.928
85.6871	0.102	0.279	0.203	0.779	2.664	10.640	0.490
85.6942	0.138	0.241	0.221	0.774	2.696	10.460	0.816
85.7013	0.129	0.247	0.209	0.788	2.689	10.460	0.636
85.7047	0.135	0.238	0.205	0.806	2.695	10.410	0.581
85.7135	0.144	0.225	0.198	0.817	2.704	10.310	0.485
85.7194	0.135	0.219	0.209	0.836	2.710	10.290	0.642
85.7255	0.119	0.214	0.208	0.881	2.712	10.310	0.608
85.7311	0.132	0.191	0.211	0.910	2.720	10.180	···
85.7375	0.140	0.172	0.204	0.952	2.742	10.070	···
85.7440	0.124	0.172	0.202	0.989	2.738	10.080	···
85.7497	0.129	0.156	0.202	1.026	2.753	10.010	···
85.7586	0.133	0.147	0.208	1.027	2.765	9.950	···
85.7652	0.136	0.144	0.209	1.028	2.768	9.920	···
85.7714	0.118	0.152	0.194	1.070	2.753	10.000	···
85.7773	0.135	0.144	0.193	1.055	2.765	9.920	···
85.7833	0.134	0.138	0.198	1.076	2.770	9.930	···
85.7916	0.127	0.150	0.195	1.079	2.755	9.970	···
86.8452	0.138	0.305	0.212	0.760	2.647	10.620	0.500

TABLE 5 (CONTINUED)

HJD	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	[Fe/H]
86.8517	0.116	0.310	0.218	0.659	2.649	10.700	0.579
86.8595	0.145	0.286	0.215	0.670	2.665	10.570	0.654
86.8680	0.125	0.296	0.218	0.690	2.658	10.660	0.649
86.8753	0.135	0.294	0.214	0.673	2.659	10.600	0.596
86.8824	0.140	0.281	0.211	0.700	2.667	10.580	0.611
86.8889	0.106	0.313	0.209	0.693	2.643	10.720	0.430
86.8950	0.132	0.294	0.195	0.733	2.652	10.590	0.326
86.9023	0.111	0.293	0.219	0.701	2.660	10.680	0.672
86.9086	0.159	0.246	0.229	0.704	2.696	10.470	0.920
86.9144	0.124	0.285	0.209	0.725	2.663	10.600	0.567
86.9199	0.119	0.285	0.200	0.739	2.660	10.620	0.433
86.9252	0.125	0.284	0.197	0.743	2.660	10.570	0.395
87.6561	0.103	0.306	0.224	0.723	2.651	10.740	0.664
87.6620	0.119	0.298	0.219	0.729	2.655	10.670	0.629
87.6679	0.131	0.293	0.211	0.705	2.658	10.580	0.562
87.6739	0.112	0.323	0.204	0.667	2.635	10.660	0.314
87.6917	0.098	0.312	0.222	0.701	2.647	10.750	0.615
87.6975	0.103	0.318	0.213	0.683	2.641	10.720	0.463
87.7045	0.114	0.295	0.216	0.707	2.658	10.670	0.622
87.7249	0.135	0.285	0.204	0.705	2.662	10.560	0.501
87.7367	0.126	0.280	0.215	0.711	2.668	10.600	0.663
87.7478	0.111	0.293	0.210	0.705	2.658	10.650	0.550
87.7564	0.096	0.304	0.218	0.699	2.652	10.700	0.600
87.7645	0.092	0.307	0.209	0.726	2.646	10.720	0.448
87.7718	0.086	0.313	0.201	0.739	2.639	10.740	0.312
87.7807	0.150	0.262	0.193	0.736	2.676	10.440	0.413
87.7905	0.145	0.250	0.207	0.717	2.689	10.440	0.606
87.8030	0.152	0.241	0.195	0.772	2.692	10.360	0.443
87.8145	0.134	0.234	0.198	0.801	2.697	10.380	0.491
87.8273	0.074	0.266	0.207	0.822	2.673	10.550	0.587
87.8370	0.107	0.218	0.180	0.923	2.704	10.260	0.227
87.8481	0.083	0.201	0.184	1.020	2.715	10.200	0.243
87.8558	0.100	0.166	0.191	1.056	2.737	10.030	···
87.8650	0.119	0.126	0.207	1.105	2.781	9.880	···
87.8735	0.111	0.142	0.189	1.107	2.762	9.890	···
87.8819	0.113	0.140	0.190	1.117	2.762	9.890	···
87.8914	0.122	0.131	0.192	1.118	2.773	9.870	···
87.9012	0.135	0.130	0.182	1.131	2.773	9.840	···
87.9095	0.138	0.131	0.176	1.130	2.771	9.860	···
88.7067	0.153	0.255	0.211	0.763	2.684	10.400	0.663
88.7272	0.093	0.310	0.209	0.761	2.643	10.690	0.432
88.7408	0.145	0.279	0.197	0.742	2.664	10.470	0.416
88.7537	0.116	0.301	0.210	0.706	2.652	10.620	0.506

TABLE 5 (CONTINUED)

HJD	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	[Fe/H]
88.7653	0.136	0.288	0.206	0.723	2.660	10.540	0.509
88.7756	0.144	0.284	0.206	0.720	2.663	10.510	0.529
88.7865	0.140	0.282	0.223	0.705	2.669	10.540	0.776
88.7964	0.113	0.307	0.222	0.689	2.651	10.670	0.641
88.8090	0.176	0.258	0.216	0.686	2.685	10.400	0.728
88.8212	0.128	0.298	0.224	0.692	2.658	10.620	0.710
88.8308	0.146	0.288	0.212	0.695	2.662	10.540	0.592
88.8412	0.150	0.298	0.188	0.718	2.647	10.520	0.217
88.8499	0.099	0.329	0.216	0.695	2.633	10.760	0.430
88.8586	0.127	0.306	0.225	0.666	2.653	10.650	0.692
88.8840	0.137	0.303	0.201	0.705	2.648	10.610	0.378
88.8979	0.154	0.284	0.222	0.678	2.668	10.550	0.758
88.9097	0.158	0.276	0.219	0.699	2.672	10.540	0.740
88.9217	0.168	0.273	0.211	0.700	2.673	10.500	0.632
89.6920	0.135	0.225	0.202	0.907	2.701	10.270	0.538
89.6991	0.164	0.193	0.206	0.890	2.720	10.130	···
89.7093	0.129	0.228	0.201	0.889	2.699	10.300	0.527
89.7150	0.146	0.219	0.192	0.881	2.706	10.240	0.391
89.7254	0.125	0.262	0.174	0.850	2.668	10.330	0.146
89.7311	0.105	0.264	0.191	0.858	2.670	10.440	0.380
89.7410	0.117	0.255	0.199	0.827	2.680	10.410	0.506
89.7461	0.124	0.258	0.177	0.842	2.672	10.380	0.201
89.7550	0.116	0.269	0.192	0.817	2.668	10.420	0.376
89.7596	0.127	0.263	0.178	0.840	2.668	10.390	0.201
89.7745	0.115	0.283	0.175	0.809	2.652	10.470	0.098
89.7839	0.101	0.292	0.181	0.831	2.646	10.530	0.135
89.7900	0.120	0.270	0.203	0.796	2.670	10.470	0.526
89.7961	0.139	0.252	0.210	0.784	2.685	10.390	0.645
89.8103	0.130	0.273	0.190	0.791	2.665	10.450	0.338
89.8189	0.102	0.296	0.191	0.799	2.647	10.580	0.249
89.8406	0.152	0.260	0.203	0.739	2.680	10.380	0.552
89.8474	0.152	0.268	0.194	0.730	2.672	10.390	0.412
89.8536	0.119	0.299	0.194	0.745	2.647	10.550	0.283
89.8605	0.137	0.279	0.214	0.708	2.669	10.490	0.662
89.8827	0.116	0.299	0.214	0.702	2.654	10.600	0.564
89.8913	0.137	0.282	0.203	0.711	2.664	10.530	0.495
89.8982	0.142	0.274	0.219	0.725	2.673	10.500	0.736
89.9041	0.119	0.286	0.203	0.732	2.660	10.660	0.469
89.9099	0.113	0.312	0.205	0.722	2.641	10.630	0.371
89.9157	0.165	0.272	0.196	0.717	2.670	10.400	0.433
90.6894	0.135	0.225	0.207	0.922	2.701	10.290	0.622
90.6964	0.164	0.193	0.206	0.890	2.720	10.130	···
90.7066	0.129	0.228	0.201	0.889	2.699	10.300	0.527

TABLE 5 (CONTINUED)

HJD	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	[Fe/H]
90.7123	0.146	0.219	0.192	0.881	2.706	10.240	0.391
90.7226	0.125	0.262	0.174	0.850	2.668	10.330	0.146
90.7284	0.105	0.264	0.191	0.858	2.670	10.440	0.380
90.7382	0.117	0.255	0.199	0.827	2.680	10.410	0.506
90.7434	0.124	0.258	0.177	0.842	2.672	10.380	0.201
90.7523	0.107	0.271	0.200	0.825	2.668	10.480	0.480
90.7569	0.127	0.263	0.178	0.840	2.668	10.390	0.201
90.7667	0.092	0.299	0.221	0.813	2.652	10.650	0.632
90.7718	0.109	0.289	0.174	0.810	2.647	10.500	0.053
90.7812	0.109	0.284	0.184	0.829	2.653	10.500	0.201
90.7873	0.120	0.270	0.203	0.796	2.670	10.470	0.526
90.7933	0.139	0.252	0.210	0.784	2.685	10.390	0.645
90.8076	0.130	0.273	0.190	0.791	2.665	10.450	0.338
90.8162	0.102	0.296	0.191	0.799	2.647	10.580	0.249
90.8379	0.143	0.261	0.212	0.751	2.680	10.440	0.672
90.8447	0.141	0.269	0.201	0.747	2.672	10.460	0.509
90.8509	0.119	0.299	0.194	0.745	2.647	10.550	0.283
90.8578	0.137	0.279	0.214	0.708	2.669	10.490	0.662
90.8800	0.116	0.299	0.214	0.702	2.654	10.600	0.564
90.8886	0.137	0.282	0.203	0.711	2.664	10.530	0.495
90.8955	0.142	0.274	0.219	0.725	2.673	10.500	0.736
90.9014	0.119	0.286	0.203	0.732	2.660	10.660	0.469
90.9072	0.113	0.312	0.205	0.722	2.641	10.630	0.371
90.9130	0.165	0.272	0.196	0.717	2.670	10.400	0.433
91.6968	0.083	0.298	0.200	0.787	2.648	10.610	0.361
91.7039	0.120	0.272	0.199	0.762	2.669	10.450	0.470
91.7185	0.137	0.253	0.215	0.766	2.686	10.410	0.719
91.7264	0.110	0.287	0.188	0.781	2.654	10.530	0.259
91.7357	0.149	0.258	0.195	0.763	2.679	10.370	0.445
91.7425	0.153	0.259	0.183	0.784	2.675	10.350	0.282
91.7470	0.124	0.278	0.198	0.758	2.664	10.510	0.434
91.7514	0.150	0.264	0.193	0.758	2.674	10.380	0.410
91.7658	0.152	0.274	0.193	0.742	2.667	10.390	0.382
91.7702	0.135	0.286	0.192	0.745	2.657	10.470	0.328
91.7753	0.154	0.272	0.183	0.762	2.665	10.400	0.253
91.7859	0.117	0.302	0.199	0.734	2.647	10.580	0.347
91.7957	0.161	0.271	0.192	0.728	2.669	10.400	0.384
91.8047	0.135	0.296	0.199	0.721	2.652	10.530	0.373
91.8181	0.143	0.295	0.195	0.734	2.651	10.530	0.324
91.8269	0.145	0.298	0.185	0.727	2.646	10.520	0.183
91.8316	0.176	0.260	0.217	0.683	2.684	10.400	0.741
91.8363	0.168	0.277	0.207	0.696	2.669	10.430	0.576
91.8412	0.107	0.319	0.223	0.673	2.643	10.730	0.592

TABLE 5 (CONTINUED)

HJD	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	[Fe/H]
91.8532	0.164	0.285	0.203	0.676	2.663	10.470	0.492
91.8579	0.137	0.316	0.196	0.681	2.637	10.590	0.245
91.8623	0.155	0.282	0.219	0.674	2.669	10.530	0.718
91.8708	0.124	0.319	0.199	0.681	2.636	10.680	0.273
91.8790	0.129	0.315	0.195	0.692	2.637	10.670	0.230
91.8890	0.140	0.299	0.219	0.669	2.657	10.620	0.650
91.8972	0.164	0.283	0.200	0.680	2.664	10.520	0.462
91.9054	0.137	0.307	0.202	0.686	2.646	10.630	0.376
93.6247	0.108	0.238	0.207	0.784	2.696	10.490	0.620
93.6331	0.105	0.242	0.206	0.805	2.692	10.460	0.607
93.6569	0.099	0.250	0.216	0.807	2.687	10.430	0.728
93.6650	0.101	0.234	0.203	0.816	2.698	10.380	0.565
93.6845	0.085	0.248	0.207	0.821	2.687	10.430	0.606
93.6972	0.088	0.251	0.198	0.825	2.683	10.420	0.483
93.7119	0.114	0.240	0.193	0.821	2.691	10.330	0.425
93.7216	0.100	0.244	0.179	0.845	2.684	10.410	0.235
93.7270	0.115	0.228	0.199	0.825	2.702	10.320	0.495
93.7381	0.108	0.244	0.197	0.801	2.689	10.360	0.481
93.7508	0.124	0.230	0.201	0.810	2.701	10.300	0.534
93.7617	0.126	0.232	0.208	0.789	2.701	10.330	0.627
93.7692	0.090	0.263	0.203	0.795	2.676	10.490	0.545
93.7808	0.096	0.266	0.215	0.782	2.676	10.550	0.696
93.7903	0.091	0.272	0.192	0.811	2.666	10.510	0.372
93.7960	0.103	0.271	0.189	0.795	2.666	10.460	0.327
93.8092	0.089	0.282	0.203	0.774	2.662	10.560	0.481
93.8186	0.104	0.283	0.203	0.750	2.662	10.490	0.486
93.8274	0.109	0.271	0.200	0.755	2.670	10.520	0.483
93.8371	0.112	0.272	0.204	0.760	2.670	10.520	0.533
93.8501	0.117	0.286	0.192	0.740	2.657	10.510	0.322
93.8588	0.107	0.292	0.206	0.723	2.657	10.560	0.493
93.8673	0.106	0.297	0.201	0.739	2.651	10.590	0.392
93.8767	0.135	0.276	0.213	0.702	2.671	10.470	0.662
93.8868	0.129	0.282	0.218	0.699	2.668	10.530	0.702
93.8953	0.129	0.285	0.210	0.705	2.664	10.540	0.579
93.9008	0.115	0.298	0.225	0.716	2.657	10.640	0.725
97.7340	0.097	0.290	0.186	0.796	2.650	10.630	0.213
97.7479	0.118	0.267	0.188	0.804	2.669	10.510	0.337
97.7528	0.105	0.284	0.189	0.789	2.656	10.560	0.285
97.7601	0.107	0.267	0.197	0.797	2.671	10.560	0.453
97.7691	0.142	0.250	0.175	0.814	2.679	10.390	0.179
97.7730	0.154	0.235	0.197	0.777	2.697	10.340	0.477
97.7839	0.109	0.281	0.169	0.808	2.652	10.530	0.019
97.7879	0.137	0.245	0.181	0.806	2.685	10.410	0.263

TABLE 5 (CONTINUED)

HJD	$E(b-y)$	$(b-y)_0$	m_0	c_0	β	V_0	[Fe/H]
97.7991	0.135	0.247	0.176	0.819	2.682	10.410	0.192
97.8031	0.136	0.243	0.185	0.807	2.687	10.400	0.310
97.8073	0.116	0.263	0.185	0.813	2.671	10.470	0.297
97.8130	0.156	0.233	0.168	0.835	2.691	10.280	0.073
97.8203	0.139	0.232	0.176	0.850	2.693	10.350	0.180
97.8279	0.131	0.231	0.186	0.857	2.696	10.360	0.327
97.8370	0.130	0.222	0.186	0.862	2.703	10.330	0.311
97.8461	0.111	0.222	0.191	0.888	2.703	10.360	0.388
97.8559	0.116	0.215	0.168	0.950	2.703	10.260	0.050
97.9190	0.142	0.143	0.169	1.123	2.757	9.880	...
All data							
Mean	0.128	0.261	0.200	0.790	2.678	10.446	0.464
Sigma	0.021	0.044	0.013	0.104	0.031	0.194	0.181
87−88							
Mean	0.125	0.274	0.201	0.760	2.669	10.521	0.448
sigma	0.023	0.032	0.016	0.076	0.020	0.144	0.193

Time shown = HJD 2451000.

TABLE 10

RESULTS OF THE ANALYSIS OF THE DATA SETS USING BREGER'S PERIOD

Set	Source	F_0	A_0	ϕ_0	F_1	A_1	ϕ_1	F_2	A_2	ϕ_2	Resid.	Zero
33000	Guman 82	0.4049	0.243	0.276	2.9046	0.203	0.890	2.3728	0.216	0.951	0.1572	11.288
34000	Guman 82	3.3112	0.306	0.447	1.8216	0.279	0.315	0.6289	0.175	0.205	0.1365	11.218
34250	Guman 82	0.5016	0.269	0.297	3.4564	0.338	0.309	3.9569	0.263	0.369	0.1572	11.250
34500	Guman 82	0.4972	0.318	0.630	4.7171	0.236	0.419	2.3733	0.222	0.745	0.1612	10.961
Sum	Guman 82	1.4061	0.416	0.807	1.9043	0.313	0.957	2.7809	0.117	0.018	0.1810	11.184
36800	Notni 63	1.3952	0.279	0.394	1.9060	0.204	0.282	5.1124	0.084	0.554	0.0863	···
42697	Jakate 78	1.4063	0.281	0.237	3.3218	0.145	0.156	1.8899	0.161	0.627	0.0906	···
48884	PP 92	2.3997	0.201	0.868	0.5391	0.123	0.440	2.8521	0.126	0.974	0.1029	10.995
51088	PP 98	1.4034	0.275	0.061	2.8506	0.173	0.987	···	···	···	0.0433	···

TABLE 11

ADJUSTED DATA WITH THE FREQUENCIES OF F&S

Set	Source	F_0	A_0	ϕ_0	F_1	A_1	ϕ_1	F_2	A_2	ϕ_2	Resid.
33000	Guman 82	1.4061	0.338	0.200	1.9043	0.254	0.053	2.3749	0.132	0.929	0.1600
34000	Guman 82	1.4061	0.278	0.215	1.9043	0.271	0.934	2.3749	0.148	0.974	0.1691
34250	Guman 82	1.4061	0.519	0.165	1.9043	0.420	0.019	2.3749	0.137	0.977	0.1478
34500	Guman 82	1.4061	0.412	0.163	1.9043	0.391	0.032	2.3749	0.225	0.023	0.1708
36800	Notni 63	1.4061	0.211	0.040	1.9043	0.207	0.909	2.3749	0.098	0.700	0.1044
42697	Jakate 78	1.4061	0.269	0.773	1.9043	0.197	0.650	2.3749	0.165	0.427	0.1132
48884	PP 92	1.4061	0.279	0.252	1.9043	0.167	0.197	2.3749	0.205	0.843	0.1054
51088	PP 98	1.4061	0.192	0.972	1.9043	0.192	0.002	2.3749	0.180	0.702	0.0420