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δ Sct-type nature of the variable V2109 Cyg[⋆,⋆⋆]

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Abstract. We present the results of simultaneous *uvbyβ* photometry carried out from 1999 to 2001 of the variable V2109 Cyg together with a spectroscopic analysis based on one high resolution spectrum obtained in 2000. From this study, the star is definitively classified as an evolved δ Sct-type variable with solar metal abundances. This conclusion is also supported by the detected multiperiodic pulsational behaviour and the observed variation of the m_1 index over the pulsation cycle. This variation is slightly reversed relative to the V light curve, in very good agreement with the m_1 variation expected from the photometric calibrations. Besides the main frequency $f_1 = 5.3745$ cd^{-1} and its first harmonic $2f_1$, a secondary peak is found at $f_2 = 5.8332$ cd^{-1} ($f_1/f_2 = 0.92$) with f_1 identified as a radial mode and f_2 as non-radial. Whereas no significant variations are found in the amplitude of f_1 from season to season, the amplitude of f_2 changes strongly. Moreover, the main period has remained constant since 1990, within the observational uncertainties. Additional secondary frequencies may also be excited in this variable.

Key words. stars: variables: δ Sct – stars: individual: V2109 Cyg – stars: oscillations – techniques: photometric, spectroscopic

1. Introduction

V2109 Cyg ($V = 7\overset{\text{m}}{.}5$, F0) is a pulsating star discovered by the Hipparcos satellite (ESA 1997). It has a period of $P = 0\overset{\text{d}}{.}1860$ and full amplitude $\Delta V = 0\overset{\text{m}}{.}16$. However, the type of variability has been subject of controversy during the last few years: in the Hipparcos catalogue it is identified as an RRc-type variable, but Kazarovets et al. (1999) proposed a δ Sct-type classification whereas Kiss et al. (1999) claimed again this star as an RRc pulsator. Finally, Rodríguez et al. (2000) re-classified this star as a δ Sct variable on the basis of its period and its Strömgren photometric indices. The importance of this topic arises from the fact that if this star is an RR Lyr-type pulsator, it would be the RR Lyr-type variable with the shortest period known up to date. In order to clarify this point new photometric and spectroscopic observations have been carried out.

2. Observations

The photometric observations were collected through the years 1999 to 2001 at Sierra Nevada Observatory (SNO), Spain (*uvbyβ* measurements using the 0.9 m telescope) and in 2000 at San Pedro Mártir Observatory (SPMO), Mexico (*uvby* photometry using the 1.5 m telescope). Both telescopes are equipped with identical six-channel *uvbyβ* spectrophotometers for simultaneous measurements in *uvby* or in the narrow and wide H_β channels (Nielsen 1983).

HD 189013 ($V = 6\overset{\text{m}}{.}89$, A2) was used as main comparison star with HD 191022 ($V = 7\overset{\text{m}}{.}44$, G0) as check star. The latter was used as comparison star by Kiss et al. (1999). Additionally, a few *uvbyβ* data of HD 193701 ($V = 6\overset{\text{m}}{.}98$, F5IV) were also collected at SNO for calibration purposes. Table 1 lists the journal of the photometric observations. In the present work no variations, within our observational errors, were found for any of the comparison stars. No noticeable nightly zero-point shifts nor short-period periodicities are present. The mean values obtained for the C2-C1 differences on each of the nights were always the same within $0\overset{\text{m}}{.}002$, as standard deviation, for any of the *vby* filters and $0\overset{\text{m}}{.}004$ in the *u* band. Moreover, when Fourier analyses are perfomed, no significant peaks are detected in the spectra. No periodicities with amplitudes larger than about 1.5 mmag are present.

In order to transform our instrumental magnitude differences into the standard *uvbyβ* system, we have used the procedure described in Rodríguez et al. (1997). The agreement found between the derived standard differences from the two observatories was very good among each other and with those found in the different catalogues available in the bibliography (Olsen 1983, 1996; Hauck & Mermilliod 1998). However, large

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⋆ Based on observations collected at the Sierra Nevada, San Pedro Mártir and Haute-Provence observatories.

⋆⋆ Tables 2, 5 and 7 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via
http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/407/1059

Table 1. Journal of observations.

Date	Observatory	Filters	Nights	Points
1999-Oct./Nov.	SNO	*uvby*	3	128
1999-October	SNO	β	2	96
2000-July	SNO	*uvby*	5	163
2000-July	SNO	β	3	76
2000-September	SPMO	*uvby*	7	176
2001-March	SNO	*uvby*	2	65

discrepancies are found for the derived values of V2109 Cyg with respect to the values published in Kiss et al. (1999), especially in the m_1 and c_1 indices. This seems to be very probably due to calibration problems by these authors as will be seen in Sect. 4. Our determined standard magnitude differences of V-C1 versus Heliocentric Julian Day have been deposited in the Commission 27 IAU Archives of Unpublished Observations, file 350E, and can also be requested from the authors.

In addition, one high resolution (42 000) spectrum of V2109 Cyg was obtained on October 6, 2000 with the 1.93 m telescope of the Haute-Provence Observatory (France). This telescope is equipped with the echelle spectrograph ELODIE. Details of the instrument are described by Baranne et al. (1996). The spectrum was reduced using the spectroscopic data reduction tasks of the IRAF package.

3. Frequencies

3.1. Analysis of new data

Period analysis, using the classical O–C method, was performed with the new times of maximum derived in the present work together with those determined by Kiss et al. (1999). The new times of maximum were calculated as an average over the three *vby* bands following the method described in Rodríguez et al. (1990). If we use a linear ephemeris, with a period of $0.^{\rm d}186049$ (from Kiss et al. 1999), to phase our data (time span of 1.43 years), we can see that this period does not work well, suggesting that the true period needs to be longer. In fact, a new linear ephemeris with origin in $T_0 = 2451464.^{\rm d}4329(\pm 0.0011)$ and period $P = 0.^{\rm d}1860652(\pm 0.0000005)$ was derived in our O–C analysis with the residuals randomly distributed around zero, as listed in Table 2. This new value is in very good agreement with that of $0.^{\rm d}1860656$ given by the Hipparcos catalogue (ESA 1997) using the data collected by this satellite between the years 1990 to 1993. Thus, it suggests that the main period of V2109 Cyg has remained constant since 1990 and no sudden period decrease has occurred between 1991 and 1998, as mentioned by Kiss et al. (1999). In fact, when a Fourier analysis is performed to the $V+y$ data of these authors, a main peak at $f = 5.3746$ cd^{-1} (that is, period of $0.^{\rm d}186060$) is found in good agreement with our results.

On the other hand, from Table 2 we see that the residuals are too large (standard deviation of the fit is $0.^{\rm d}0040$) as compared with the estimated times of maximum error bars ($\sim 0.^{\rm d}0007$). This means that a secondary period is probably present in the light curves. This agrees well with the differences found between the light curves obtained in different nights, as shown in Fig. 1 for the individual light curves obtained at SPMO.

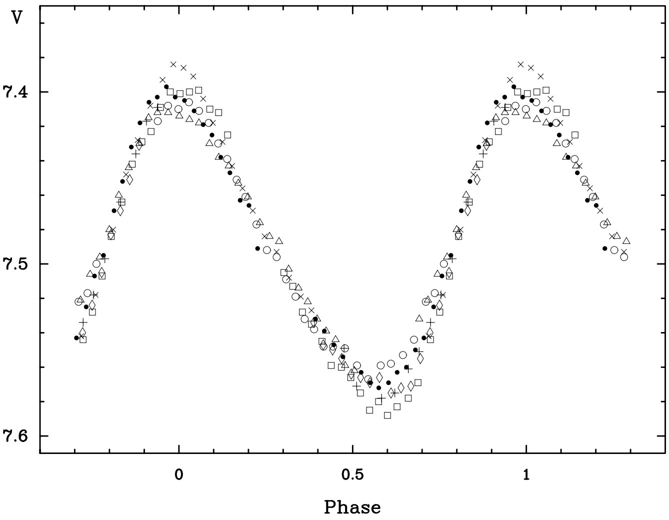

Fig. 1. Nightly light curves of V2109 Cyg collected at San Pedro Mártir Observatory during seven nights in September, 2000. Different symbols correspond to different nights.

Table 3. Frequencies and amplitude signal/noise ratios obtained for each *uvby* filter.

Frequency (cd^{-1})	$S/N(u)$	$S/N(v)$	$S/N(b)$	$S/N(y)$
$f_1 = 5.3745$	44.6	66.8	65.7	69.9
$2f_1 = 10.7490$	6.3	8.1	8.0	8.5
$f_2 = 5.8332$	5.0	7.8	7.9	8.3

This was confirmed when a Fourier analysis was made of our data collected in the year 2000 (our largest data set), following the method described in Rodríguez et al. (1998). When the v filter was analysed, a main peak was found at $f_1 = 5.3745$ cd^{-1}. A secondary peak was also detected at $f_2 = 5.8332$ cd^{-1} after f_1 and its first harmonic ($2f_1$) were removed from the spectra. The corresponding power spectra are shown in Fig. 2. When these peaks are extracted, no new significant periodicities are present in our data. Similar results were obtained in the other filters.

Table 3 lists the amplitude signal/noise (S/N) ratios obtained for each of the frequencies and filters, following Handler et al. (1996). As shown, the three peaks are intrinsic of the variable (Breger et al. 1993, 1996). Figure 3 shows the 2000 data set phased for each frequency after prewhitening of the other one. The results of the Fourier analysis are listed in Table 4. The amplitude ratios and phase shifts determined for different colours indicate that the secondary peak is also due to pulsation.

From Table 4 it can also be seen that the residuals in *vby* are smaller when the wavelength is larger. This suggests that more frequencies are remaining. This is also supported by the fact that these residuals are much larger than the white noise found for the C2-C1 spectra (e.g., in the filter v we have 8.7 mmag

Table 4. Results from the Fourier analysis applied to the *uvby* data collected in the year 2000.

	u		*v*		*b*		*y*		*b−y*		c_1	
Frequency (cd^{-1})	*A* (mmag)	φ (rad)	*A* (mmag)	φ (rad)	*A* (mmag)	φ (rad)	*A* (mmag)	φ (rad)	*A* (mmag)	φ (rad)	*A* (mmag)	φ (rad)
	±0.96		±0.67		±0.56		±0.47		±0.27		±0.91	
f_1 = 5.3745	98.17	3.314	126.94	3.248	105.09	3.230	83.91	3.201	21.34	3.341	51.05	0.019
		11		6		6		6		14		20
$2f_1$ = 10.7490	12.51	3.045	16.06	2.863	13.61	2.840	11.07	2.879	2.59	2.671	6.51	5.701
		81		44		43		45		108		145
f_2 = 5.8332	11.05	4.867	14.89	4.817	12.66	4.839	10.01	4.912	2.77	4.576	6.15	1.538
		85		44		43		46		94		144
mean value	0.8422		0.8774		0.7386		0.6034		0.1353		−0.1738	
(mag)	7		5		4		4		2		7	
residuals	12.5		8.7		7.2		6.1		3.5		11.8	
(mmag)												
T_{or}(HJD)	2451461.4245											

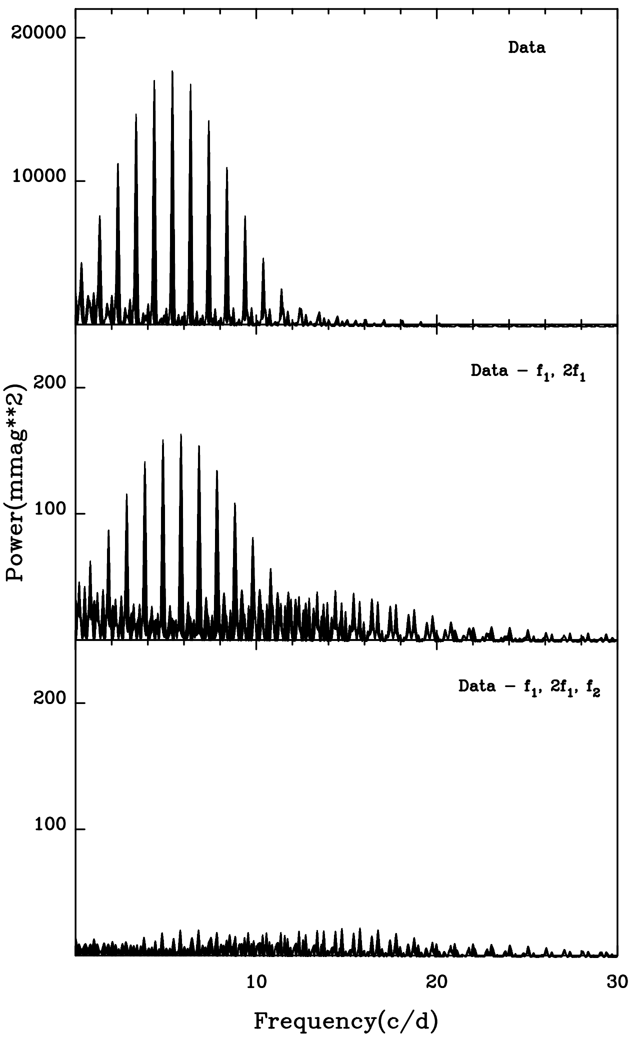

Fig. 2. Power spectra in the *v* band before and after removing the frequencies detected in the Fourier analysis.

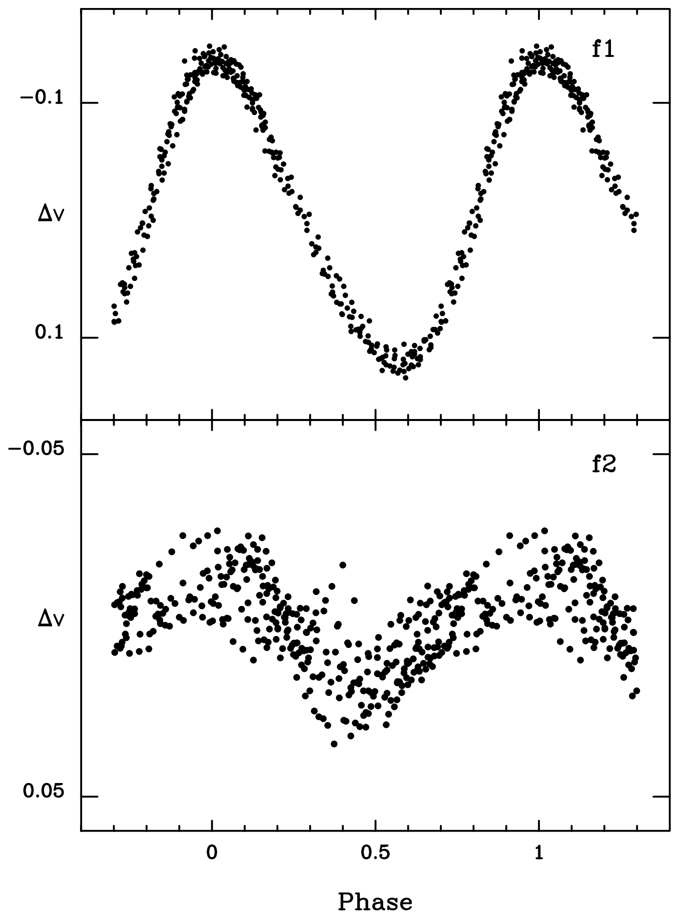

Fig. 3. Light curves phased for each frequency after removing the other. *Top panel*: for f_1. *Bottom panel*: for f_2.

for V-C1, but only 3.1 mmag for C2-C1) taking into account that C2 and the variable are of similar brightness.

The existence of f_2 is also confirmed when the 2000 data sets collected at SPMO and SNO are independently analysed. However, this cannot be found with our 1999 or 2001 data sets, because both the number of points and hours of observation are insufficient.

3.2. New analysis of old data

In order to investigate the existence of f_2 in other data sets, the measurements collected in 1998 by Kiss et al. (1999), in both Strömgren and Johnson photometry, were analysed. The V and y data were merged and then investigated by means of Fourier analysis. The main peak was found at 5.3746 cd^{-1} in good agreement with our results. When this frequency and its first harmonic were removed from the spectra, no new peaks were present with amplitudes larger than 6.0 mmag. Similar results are found when the vby and BV data are analysed separately. Table 5 shows the results of the Fourier fitting when $f_1 = 5.3745$ cd^{-1} and $2f_1$ are simultaneously extracted. Hence, f_2 is not significant in these data sets, but the vby residuals decrease from filters v to b and y suggesting that some periodicities are still remaining in the light curves. In the case of the BV data, the noise level in the V filter is too high dominating over the eventually remaining signals.

The Hp data collected by the Hipparcos satellite (ESA 1997) were also investigated. The main peak is detected at 5.3745 cd^{-1} together with its first harmonic. When f_1 and $2f_1$ are removed from the amplitude spectra, a flat spectrum remains with a level of about 6.0 mmag and no new peaks are detectable. The results of the fitting are listed in Table 5. The amplitude of f_1 in Hp magnitudes is of 86.33(±1.72) mmag which means an amplitude in the Johnson V filter of ΔV = 78.4(±2.5) mmag (Rodríguez 1999).

3.3. Discussion

In summary, the secondary frequency $f_2 = 5.8332$ cd^{-1} seems to be well established in the measurements obtained during the year 2000 with an amplitude of 10 mmag in the $y = V$ filter. However, its existence has not been proven in the data collected during 1998 by Kiss et al. (1999) nor during the interval 1990–1993 by the Hipparcos satellite (ESA 1997). If this frequency is present in these data sets, it should be with an amplitude smaller than about 6 mmag. On the other hand, no significant variations are found in the amplitude of the main frequency $f_1 = 5.3745$ cd^{-1}.

Moreover, the corresponding period ratio $P_2/P_1 = 0.92$ indicates that at least one of the two frequencies corresponds to a nonradial mode. From Table 4, we can also see that the phase differences between the light curves in v and y or b and y are positive for f_1 and negative for f_2, suggesting that the main frequency corresponds to a radial mode while f_2 is nonradial (Garrido et al. 1990). This is also supported by the observed phase shifts between $b - y$ and y. Despite the error bars being too large in the Fourier fitting of the 1998 data sets (Table 5), the observed phase shifts seem to confirm that f_1 corresponds to a radial mode.

This resembles the high amplitude δ Sct star RY Lep, where besides the main radial mode of constant amplitude, a secondary non-radial mode with variable amplitude within a time scale of years has been recently detected (Laney et al. 2003). Indeed, the secondary frequency is not detectable in some observing runs. Secondary frequencies with variable amplitudes are also detected in the medium amplitude δ Sct-type star AN Lyn (Zhou 2002) and strong amplitude variations of the main frequency are also found in the low amplitude δ Sct variable 28 And (Rodríguez et al. 1998) where the secondary frequency is commonly below the limit of photometric detectability.

Table 6. $uvby\beta$ indices obtained for V2109 Cyg and comparison stars. The pairs below the star names are the number of points collected for each object in $uvby$ and β, respectively. For comparison, the values available from the bibliography are listed in the bottom part. The values listed for the variable are "mean values" based on the normal points along the cycle (Table 7). For this star, the comparison with the earlier available Strömgren indices (bottom part) must be made at phase 0.15 where the indices are, according to Table 7: $V = 7\overset{m}{.}438$, $b - y = 0\overset{m}{.}214$, $m_1 = 0\overset{m}{.}171$ and $c_1 = 0\overset{m}{.}874$.

Star	V	$b - y$	m_1	c_1	β
V2109 Cyg	7.494	0.226	0.172	0.838	2.740
(532, 172)	59	15	1	36	13
C1 = HD 189013	6.890	0.089	0.171	1.011	2.846
(475, 62)					
C2 = HD 191022	7.438	0.413	0.192	0.391	2.603
(252, 37)	3	3	3	10	7
C3 = HD 193701	6.981	0.301	0.167	0.503	2.659
(5,5)	5	3	3	3	5
V2109 Cyg	7.435	0.202	0.183	0.873	–
C1 = HD 189013	6.885	0.089	0.176	1.015	2.843
C2 = HD 191022	7.444	0.410	0.190	0.382	2.602
C3 = HD 193701	6.978	0.307	0.162	0.512	2.663

4. Photometry

With the aim of deriving the $uvby\beta$ indices for each of the stars observed in the present work, we followed the method described in Rodríguez et al. (2003). Thus, we use the $uvby\beta$ indices listed in earlier catalogues for each of the three comparison stars as zero-points and then, derive the indices for the remaining objects. In the case of C1 and C3, the more homogeneous catalogue of Olsen (1996) was used, but that of Hauck & Mermilliod (1998) was chosen for C2 (this star was not available in the former catalogue). The corresponding values are listed in the lower part of Table 6. The new derived indices for each of the comparison stars are presented in the upper part of the same table together with the number of points collected and the errors, as the standard deviations of the magnitude differences relative to C1. Good agreement is found between our derived indices and those found in earlier catalogues. This is also true when we compare with the values of C1 and C3 given in the other available lists of Olsen (1983) and Hauck & Mermilliod (1998).

In the case of V2109 Cyg, we list the mean values over the pulsation cycle based on the normal points of Table 7 (the large sigma values are due to the intrinsic variation of the star). These normal points were calculated according to the standard magnitude differences of V-C1 and the indices derived for C1. As it can be seen, some discrepancies seem to be present for the V and c_1 values of V2109 Cyg as compared with the indices in the literature (Olsen 1996). However, these indices are based in a few points obtained by Olsen (1983) during only one night

Table 8. Reddening and derived physical parameters for V2109 Cyg.

Parameter	Mean value	Sigma/Error	Range
E_{b-y}	$0\overset{\mathrm{m}}{.}037$	$0\overset{\mathrm{m}}{.}001$	–
$(b-y)_0$	$0\overset{\mathrm{m}}{.}189$	$0\overset{\mathrm{m}}{.}015$	$0\overset{\mathrm{m}}{.}168$–$0\overset{\mathrm{m}}{.}208$
m_0	$0\overset{\mathrm{m}}{.}184$	$0\overset{\mathrm{m}}{.}001$	$0\overset{\mathrm{m}}{.}183$–$0\overset{\mathrm{m}}{.}185$
c_0	$0\overset{\mathrm{m}}{.}831$	$0\overset{\mathrm{m}}{.}036$	$0\overset{\mathrm{m}}{.}883$–$0\overset{\mathrm{m}}{.}785$
δm_1	$-0\overset{\mathrm{m}}{.}001$	$0\overset{\mathrm{m}}{.}004$	$0\overset{\mathrm{m}}{.}005$–$-0\overset{\mathrm{m}}{.}007$
δc_1	$0\overset{\mathrm{m}}{.}177$	$0\overset{\mathrm{m}}{.}011$	$0\overset{\mathrm{m}}{.}150$–$0\overset{\mathrm{m}}{.}190$
[Me/H] (dex)	0.14	0.1	–
M_v	$1\overset{\mathrm{m}}{.}14$	$0\overset{\mathrm{m}}{.}3$	–
$M_{\rm bol}$	$1\overset{\mathrm{m}}{.}15$	$0\overset{\mathrm{m}}{.}3$	–
D.M.	$6\overset{\mathrm{m}}{.}19$	$0\overset{\mathrm{m}}{.}3$	–
$T_{\rm e}$ (K)	7080	110	7240–6940
$\log g$ (dex)	3.67	0.03	3.72–3.62
Age (Gyr)	1.0–1.4	$0\overset{\mathrm{m}}{.}1$	–
$M/M_\odot$	2.09–2.00	$0\overset{\mathrm{m}}{.}1$	–

and the corresponding phase is unknown, but very probably near the light maximum. In fact, if we compare with our normal points at phase 0.15 (Table 7), the agreement is very good.

The indices listed in Table 6 for each of the comparison stars are also in good agreement with the spectral types published in the literature (Simbad 2002). They indicate that C1 is placed inside the δ Sct instability region whereas C2 and C3 are too cool to be both γ Dor or δ Sct-type pulsators.

4.1. Physical parameters

The V light and colour index variations over the main pulsational cycle were phased in Fig. 4 according to the linear ephemeris derived in Sect. 3. Normal points every 0.05 units of phase were calculated and listed in Table 7. Their standard errors are typically of $0\overset{\mathrm{m}}{.}002$, $0\overset{\mathrm{m}}{.}001$, $0\overset{\mathrm{m}}{.}001$, $0\overset{\mathrm{m}}{.}003$ and $0\overset{\mathrm{m}}{.}004$ in V, $b-y$, m_1, c_1 and β, respectively. The method described in Rodríguez et al. (2001) was used to estimate the physical parameters of V2109 Cyg and their variation along the pulsation cycle. Thus, using the Crawford's (1979) calibrations, the reddening can be derived by comparing the intrinsic and observed $b-y$ values at normal points along the cycle. In this way, a mean colour excess of $E_{b-y} = 0\overset{\mathrm{m}}{.}037(\pm 0.001)$ is obtained. The results are summarized in Table 8 indicating that this star is a normal Population I δ Sct-type variable with approximately solar metal abundances and slightly evolved. The location of V2109 Cyg in the H-R diagram is shown in Fig. 5, together with the sample of known δ Sct-type variables.

In deriving its luminosity, the obtained photometric value ($M_v(\mathrm{ph}) = 1\overset{\mathrm{m}}{.}39(\pm 0.3)$) and the one determined from its Hipparcos parallax ($M_v(\pi) = 0\overset{\mathrm{m}}{.}88(\pm 0.27)$, ESA 1997) were averaged. The metal content [Me/H] was calculated from the δm_1 parameter at minimum light (phases between 0.5 and 0.7) where the metal lines are strongest and m_1 is most sensitive to abundance differences. In this case $\delta m_{1\rm min} = -0\overset{\mathrm{m}}{.}006$ and a value of [Me/H] = 0.14 is obtained using the Smalley's (1993) calibration for metal abundances. Figure 6 presents the changes in effective temperature and surface gravity in a (c_1, $b-y$) versus ($T_{\rm e}$, $\log g$) grid for [Me/H] = 0.0 (Smalley & Kupka 1997). If the evolutionary tracks for $Z = 0.02$ from Claret (1995) are

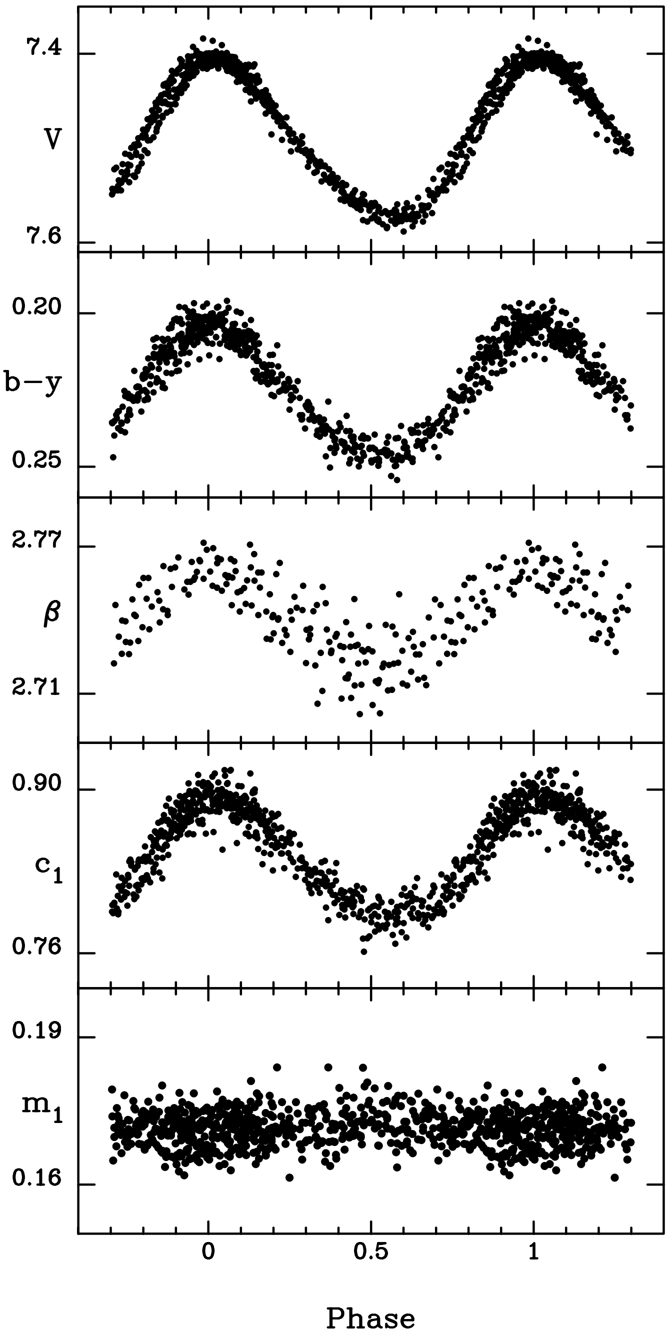

Fig. 4. Light and colour phase diagrams over the main pulsation cycle.

used, the position of the star is close to the overall contraction phase. Assuming the star is still in the main sequence stage, a mass of 2.09(±0.1) $M_\odot$ and an age of 1.0(±0.1) Gyr are estimated. If the star had already evolved off the main sequence, values of 2.00 $M_\odot$ and 1.4 Gyr are found.

4.2. m_1-index variation

The above conclusion on the δ Sct nature of V2109 Cyg is also supported by the behaviour of the m_1 index along the pulsational cycle.

The metallicity of this variable can also be derived using the observed variation of the m_1 index over the pulsation cycle

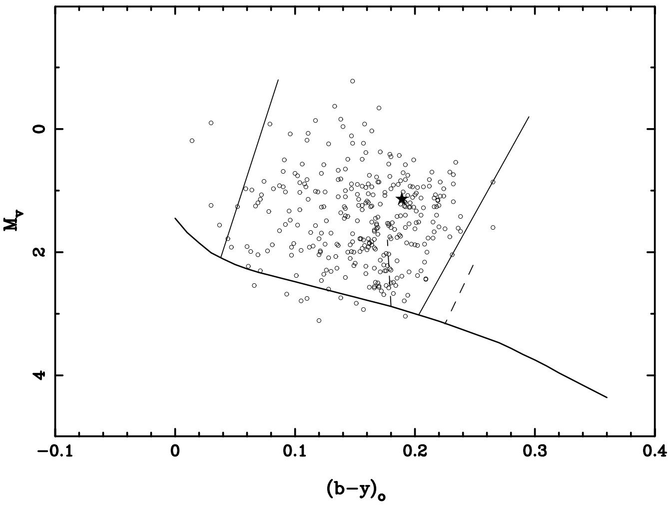

Fig. 5. Location of V2109 Cyg (star) in the H-R diagram together with the sample of δ Sct-type pulsators from Rodríguez & Breger (2001). The edges of the observational γ Dor region (dashed lines), from Handler & Shobbrook (2002), are also shown.

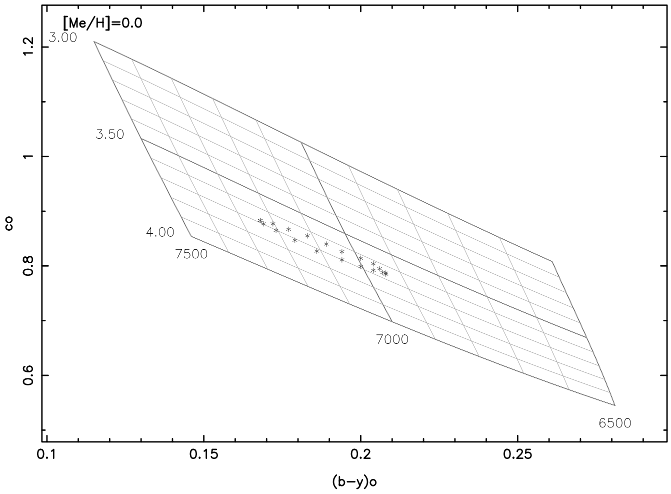

Fig. 6. Observed loop in the (c_1, $b-y$) diagram. T_e and log g lines are from Smalley & Kupka (1997) for [Me/H] = 0.0.

(Rodríguez et al. 1991). This variation is slightly reversed with respect to the V light curve, as shown in Fig. 4, suggesting solar metal abundances for a star in a similar evolutionary stage as V2109 Cyg ($<T_e>$ = 7080 K, $<\log g>$ = 3.67). The same behaviour is shown in Fig. 1 of Kiss et al. (1999).

From our data, we find a total variation of $\Delta m_1 = -0\overset{\mathrm{m}}{.}002$ (see Table 7) along the pulsational cycle (the negative sign means that m_1 is higher when the luminosity or temperature are lower and viceversa). Then, a variation of $0\overset{\mathrm{m}}{.}012$ (in the same sense of the light curve) is found for the metallicity δm_1 parameter over the pulsation cycle. This means (the total observed variation in the index β is $\Delta\beta = 0\overset{\mathrm{m}}{.}038$) a δm_1 variation of $0\overset{\mathrm{m}}{.}032$ per $0\overset{\mathrm{m}}{.}1$ variation in the β index as shown in Table 9. This variation is similar to that found for other high amplitude δ Sct stars, in particular RY Lep which presents [Me/H] = 0.2, $<T_e>$ = 7010 K and $<\log g>$ = 3.43 (Rodríguez et al. 1995).

In the case of V2109 Cyg, $<\beta> = 2\overset{\mathrm{m}}{.}740$ and $<\log g>$ = 3.67. Hence, taking into account the observed variation $\Delta m_1 = -0\overset{\mathrm{m}}{.}002$, we find a metal content of [Me/H] = 0.14 using the (Δm_1^*, β) grids of Rodríguez et al. (1991). This is in perfect agreement with the value previously obtained in Table 8. However, if the value of [Me/H] = −0.9 (Kiss et al. 1999) is assumed, a variation of $\Delta m_1 = +0\overset{\mathrm{m}}{.}012$ should be expected over the pulsation cycle of V2109 Cyg in bad agreement with the observations. Thus, it is followed that V2109 Cyg is a Population I δ Sct-type variable rather than a RR Lyr star.

5. Abundance analysis

The same conclusion on the nature of V2109 Cyg is also supported by the analysis of abundances carried out on the high resolution spectrum obtained with the echelle spectrograph ELODIE.

Before performing a line synthesis analysis of the spectrum, we estimated its effective temperature T_e by comparing the width of H_α at residual intensities between 0.7 and 0.9, with those of the theoretical profiles calculated by Kurucz (1993) for all gravities. We found T_e between 6500 and 6800 K as initial values for the synthesis analysis.

We have used ATLAS9 (Kurucz 1993) model atmospheres as an input to the 1997 version of LTE line synthesis program MOOG first described in Sneden (1973). The procedure assumes plane-parallel atmospheres, hydrostatic equilibrium and LTE.

We have worked without prejudice of the RR Lyr or δ Sct nature of the star in assigning initial values to $\log g$. We used excitation equilibrium of Fe I lines to get a preliminary estimate of T_e, requiring that the derived abundances be independent of the lower excitation potential of the lines, followed by ionisation equilibrium of Fe I/Fe II, Ti I/Ti II and Cr I/Cr II to arrive at a satisfactory estimate of T_e and log g. The microturbulence velocity ξ_t was estimated by requiring that weak, medium and strong lines give a consistent value of abundance. The atmospheric parameters found were T_e = 7000(±200) K, log g = 3.50(±0.25) dex and ξ_t = 4.85(±0.20) km s^{-1} in good agreement with those values obtained from photometric calibrations (Table 8).

The derived elemental abundances are listed in Table 10. The discussion on the uncertainties in the elemental abundances obtained by the above procedure can be found in Arellano Ferro et al. (2001). The errors in [X/H] elemental abundances can be found by dividing the standard deviations by the square root of the number of lines used given in Table 10.

Recently, Kiss et al. (1999) concluded that the star is a RR Lyr based upon their Strömgren photometry and a number of empirical calibrations. These authors estimated T_e = 6800(±200) K, log g = 2.7(±0.2) and [Fe/H] = −0.9(±0.02). Our detailed atmospheric analysis does not support their conclusions. Based on 122 Fe I and 16 Fe II lines cleanly seen in our high resolution spectrum, we find that V2109 Cyg has solar iron and calcium abundance, precluding the classification of this object as an RR Lyr star. Moreover, a mean value of [X/H] = 0.07(±0.04) dex is obtained from Table 10

Table 9. Observed metallicity index variation for V2109 Cyg together with some known high amplitude δ Sct-type variables from Rodríguez et al. (1991). $\Delta\delta m_1{}^*$ means variation of the δm_1 parameter per each $0^{\rm m}.1$ variation in the β index.

Star	Period (days)	ΔV (mag)	[Me/H] (dex)	$<\beta>$ (mag)	$\Delta\beta$ (mag)	Δm_1 (mag)	$<\delta m_1>$ (mag)	$\Delta\delta m_1{}^*$ (mag)
RS Gru	0.1470	0.49	–0.3	2.76	0.112	0.013	0.035	0.020
RY Lep	0.2254	0.35	0.2	2.71	0.073	–0.011	0.004	0.030
V1719 Cyg	0.2673	0.31	0.5	2.71	0.071	–0.031	–0.015	0.050
V2109 Cyg	0.1861	0.16	0.14	2.740	0.038	–0.002	–0.001	0.032

Table 10. Elemental abundances for V2109 Cyg. The solar abundances are taken from Grevesse et al. (1996). N is the number of lines included in the calculation.

Species	$\log \epsilon_\odot$	[X/H]	s.d.	N	[X/Fe]
C I	8.56	−0.88		1	−0.85
Mg I	7.58	−0.15	±0.10	4	−0.12
Si I	7.55	+0.71	±0.30	2	+0.74
Si II	7.55	+0.45		1	+0.48
Ca I	6.35	+0.17	±0.11	17	+0.20
Sc II	3.10	+0.61	±0.41	4	+0.64
Ti I	4.99	+0.02		1	+0.05
Ti II	4.99	+0.18	±0.23	17	+0.21
V I	4.00	−0.03		1	+0.00
Cr I	5.67	−0.02	±0.05	8	+0.01
Cr II	5.67	+0.06	±0.15	12	+0.09
Mn I	5.39	+0.01	±0.02	2	+0.04
Fe I	7.52	−0.03	±0.18	122	
Fe II	7.52	−0.03	±0.15	16	
Co I	4.92	−0.22		1	−0.19
Ni I	6.25	+0.05	±0.12	10	+0.08
Zn I	4.60	−0.20		1	−0.17
Y II	2.24	+0.48	±0.19	4	+0.51
Zr II	2.60	+0.37	±0.29	2	+0.40
Ba II	2.13	+0.49	±0.23	4	+0.52
Ce II	1.55	+0.13	±0.04	2	+0.16

(calculated as an average with weighting according to the corresponding error bars) in very good agreement with that of [Me/H] = 0.14(±0.1) dex derived from photometry.

Therefore our abundances analysis of the atmosphere of V2109 Cyg does not support its classification as an RR Lyr star but confirms the δ Sct classification obtained independently on pulsational arguments.

As s-process elements can only be formed in the hot bottom burning convection region of stars ascending the AGB (e.g. Arellano Ferro et al. 2001), small overabundances of Y, Zr, Ba and Ce in this mildly evolved star are probably explained as an inheritance of the star from the original star-forming cloud.

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