

General properties of RS CVn systems

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Accepted 1987 November 17. Received 1987 November 16; in original form 1987
September 23

Summary. In this work we analyse the behaviour of 22 members of the RS CVn family whose absolute parameters are known by observation. We have carried out a study in comparison with detached and normal-evolution systems in order to obtain some general properties of this group of active binaries and test the evolutionary status. A comparison with evolutionary tracks of several metallicities and helium contents shows that there is a trend in these stars to have metal abundances equal to or larger than the solar one. The results are discussed in the light of the peculiar characteristics of this kind of binaries.

1 Introduction

In general, the study of binary systems is one of the most important research fields in stellar astrophysics because it provides the only way to measure directly the absolute dimensions of the stars, and so it is the starting point to calibrate the fundamental astrophysical relations [see for instance, Popper (1980) and many of the works of the *IAU Symposium No. 111, Calibration of Fundamental Stellar Quantities* (1985)].

In particular, the study of some special classes of binary systems, namely, those containing late-type stars and showing chromospheric and coronal activity, presents an additional interest because it allows relations between the observed surface activity, inherent structural parameters of the systems and rotation rates, to be established. Henceforth, and following the usual definition, the term ‘activity’ refers to all the phenomena related to structures in the outer atmospheric layers of the stars whose manifestation is the appearance of enhanced chromospheric, transition region and coronal emission.

Since the early works of Wilson (1966) it has been known that some components of binary

systems show enhanced chromospheric activity in comparison with other single stars of the same effective temperature and luminosity class. The first detection of chromospheres in stars (both single and binaries) were made in the optical range, more precisely in the Ca II *H* and *K* lines, but recently, far-UV and X-ray observations have confirmed the existence of hotter atmospheric layers qualitatively similar to the solar transition region and corona (Linsky 1980, 1985; Jordan 1986).

There have been several attempts to classify active single and binary stars into groups, according to specific characteristics. Some typical families are; the BY Dra systems, defined by Bopp & Fekel (1977); the WUMa systems (Mochnecki 1981; Maceroni, Milano & Russo 1985); the FK Com stars (Bopp & Stencel 1981) and the group RS CVn, which will be studied in this paper.

It is our purpose here to analyse the behaviour of the RS CVn stars in comparison with detached and normal-evolution systems, to obtain some general properties and test their evolutionary status and chemical composition.

2 The RS CVn family

This group of binaries takes its name from the prototype, the variable RS of the constellation Canes Venatici. Although many of the members have been studied for some decades, the systematic monitoring of them has its starting point in the work of Hall (1976), who proposed a definition of 'RS CVn system' if a binary fulfils the following characteristics:

- (i) Orbital period from 1 to 14 day.
- (ii) Strong emission in the Ca II *H* and *K* lines.
- (iii) A hot component with spectral type F or G and luminosity class IV or V.

Since 1976, the list of RS CVn stars has grown – from 24 to 69 members reported by Hall (1981) – and there are included some systems with orbital period larger than 14 day such as λ And (G8III–IV+?; $P=20.5$ day) and α Aur (G0III+G5III), $P=104.0$ day), for which reason perhaps it would be more convenient to adopt a definition based on the presence of activity, along with other properties, instead of the orbital period (Linsky 1984). We shall discuss this point below.

Hall also gives two more characteristics seen in a large portion – but not in all – of the systems classified as RS CVn in 1976:

- (i) The *H* and *K* emission arises either from the cool star or from both components.
- (ii) The presence of a distortion in the light curve outside of eclipse.

The second property, today considered as fundamental to define a RS CVn system, suggests the presence of dark spots on the surface of the active star (Eaton & Hall 1979; Rodono *et al.* 1987) with a magnetic origin, by solar analogy.

Fekel, Moffet & Henry (1986) discussed the best way to define unambiguously each group of active stars, in the light of the great amount of observational data obtained in recent years. The authors claim that it is not always obvious in which group a given active star must be included because in most cases the characteristics defining the several families overlap. With respect to the RS CVn group it seems that, in order to define properly its representative characteristics, more attention should be paid to evolutionary considerations and to the fact of presence of activity in the components of the systems, instead of, for instance, constraining the inclusion of a given star into the group to a restricted orbital period interval. In the list of Hall (1981) there are included both systems whose components remain on the main sequence and systems in which one or both components are subgiants or giants and the differences between them are, obviously, substantial.

From these arguments, Fekel *et al.* (1986) suggest the use of the three following properties to define a RS CVn system:

- (i) At least one star must show intense emission in the *H* and *K* lines of Ca II.
- (ii) The system must present periodical variations in the luminosity, but not due to pulsation, eclipses or ellipticity.
- (iii) The more active star must have a spectral type F, G or K, subgiant or giant, i.e. be evolved.

As we can see, the authors do not consider the orbital period as a defining characteristic for a RS CVn system.

According to the third point of this new definition, at least 7 of the 69 systems given by Hall (1981) should be eliminated as members of the RS CVn family, because both their components have luminosity class V: RU Cnc (dF9+dF9), σ^2 CrB (G0V+G0V), CG Cyg (G9.5V+K3V), ASDra (G3V+K0V), ER Vul (G0V+G5V), HD 108102 (F8V+F8V) and HD 166181 (G5V+dM).

The evolutionary status of these systems, as we shall see below, is far from clear. Hall (1972) argued that the secondary component in RS CVn systems could be in a pre-main-sequence phase. However, neither close nebulosities have been found nor has the presence of Li lines been reported for these stars. Popper & Ulrich (1977) claim that the components of RS CVn systems have evolved in the same way as single stars, but modified by the process of a slow mass exchange ($\leq 5 \times 10^{-11} M_{\odot} \text{yr}^{-1}$). Mullan (1982), by placing the stars in a diagram separating objects with and without emergent mass flows, suggests that the subgiant stars, whose spectral types are very similar to those of the cool components in many RS CVn systems, are very near to the dividing line, so that it is likely that the RS CVn binaries are losing mass at a relatively fast rate. This phenomenon must be recent in the life of these stars because the mass loss rate computed by Mullan ($\leq 2 \times 10^{-9} M_{\odot} \text{yr}^{-1}$) cannot be maintained over the entire existence of the system ($\sim 10^9$ yr). On the other hand, an eventual evolution of some RS CVn systems towards symbiotic stars has been suggested by Blair *et al.* (1981).

3 General properties

In this part of the work we shall analyse some properties and aspects of the evolutionary status of this family of binaries by using an up-to-date collection of the most accurate data (masses, radii and temperatures) for 22 systems taken from published papers. This work of compilation is not always an easy task. The absolute dimensions of the RS CVn systems are provisional in most cases, partly because of the photometric variability, which makes it difficult to determine a non-perturbed light curve, and partly because of the small number of accurate observations available. Nevertheless, some favourable cases show total or partial eclipses allowing a reliable determination of the orbit inclination and the relative radii. On the other hand it is necessary to point out that the computation of effective temperatures from colour indices is full of difficulties owing to the nature of the light curves.

We show in Table 1 the masses, radii, effective temperatures and, in some cases, colour indices for 22 systems for which there exist studies both of light curves and radial velocity curves. Our compilation was aimed at attaining a set of well-determined masses and radii, so that, in a few cases, specified in the Notes to Table 1 we have assigned the effective temperature according to the spectral types. Note that four systems do not fulfil the definition suggested by Fekel *et al.* (1986), but it is useful to include them in order to have also in the sample main-sequence active systems considered by Hall to be RS CVns.

In order to compare with other binary systems not belonging to the RS CVn family, we have

Table 1. Parameters of the RSCVn systems.

	P(days)	Spectral type	M _h	M _c	R _h	R _c	T _h	T _c	(B-V) _h	(B-V) _c
1 RT And	0.62893	F8 V	1.50	0.99	1.35	1.00	6100	5780		
2 SS Boo	7.60608	G0 V	1.0	1.0	1.31	3.28	5900	4400	+0.59	+1.01
3 SV Cam	0.59307	G3 V	1.0	0.7	1.28	0.88	5330	4400		
4 RZ Cnc	21.6430	K1 III	3.20	0.54	10.2	12.2	4270	3850	+1.08	+1.40
5 RS CVn	4.79789	F4 V-IV	1.33	1.39	1.92	4.01	6500	4685		
6 UX Com	3.64239	G2 V	0.95	1.12	1.0	2.5	5900	4300	+0.63	+1.05
7 RT CrB	5.11710	G0	1.27	1.34	2.65	2.65	5920	5230		
8 CG Cyg	0.63114	G2	0.54	0.54	0.70	0.89	5300	4600		
9 WW Dra	4.62958	G2	1.4	1.4	2.3	3.9	5900	4700	+0.60	+0.97
10 RZ Eri	39.2821	Am	1.74	1.74	3.7	12.6	6500	5000	+0.43	+0.91
11 Z Her	3.99281	F5 V-IV	1.23	1.10	1.69	2.60	6300	4900	+0.47	+0.91
12 MM Her	7.96033	G2 V	1.18	1.27	1.58	2.83	5860	4550	+0.63	+1.06
13 AR Lac	1.98391	G2 IV	1.35	1.35	1.54	2.81	5600	4700		
14 RT Lac	5.07402	K1 IV	1.50	0.60	4.29	4.69	5715	5300		
15 UV Leo	0.60008	G2 V	0.99	0.92	1.08	1.08	5860	5860	+0.62	+0.62
16 AR Mon	21.2091	G8 III	2.70	0.80	10.8	14.2	4570	3890	+0.95	+1.30
17 LX Per	8.03804	G0 V	1.33	1.39	1.6	3.16	5800	4770		
18 SZ Psc	3.96582	F5-8 V	1.38	1.87	1.50	5.48	6100	4700		
19 UV Psc	0.86104	G4-6 V	1.20	0.90	1.24	0.93	5500	5000	+0.72	+0.89
20 TY Pyx	3.19859	G2 IV	1.22	1.20	1.59	1.68	5400	5340		
21 RW UMa	7.32825	F9 V	1.50	1.45	2.0	3.8	6300	4400		
22 ER Vul	0.69809	G0 V	1.10	1.02	1.27	1.19	5900	5520		

Notes

- 1 Masses and radii from Payne-Gaposchkin (1946) and Dean (1984). Temperatures obtained by means of the Popper's (1980) calibration from the spectral types given by Dean.
- 2 Masses, $B-V$ and temperatures from Popper (1980), radii from Wilson *et al.* (1983).
- 3 Masses and temperature of the hot component from Cellino, Scaltriti & Busso (1985), radii from Budding, Kadouri & Giménez (1982), temperature of the cool component adopted following the Popper's calibration and the spectral type given by Cellino *et al.*
- 4 Masses, radii, temperatures and colour indices taken from Popper (1980).
- 5 Masses from Popper (1980) adopting $i=86^\circ$, radii from Ludington (1978), temperatures from Eaton & Hall (1979).
- 6 Masses and radii from Popper & Ulrich (1977) assuming $i=90^\circ$, colour indices from Popper (1980), temperatures and spectral type of the cool component assigned from the Popper's data.
- 7 Masses from Popper & Ulrich (1977), radii from Ibanoglu *et al.* (1985), temperature of the hot component assigned according to its mass and radii, temperature of the cool component computed from the ratio of effective temperatures given by Ibanoglu *et al.*
- 8 Masses, radii and temperatures from Naftilan & Milone (1985).
- 9 Masses and radii from Popper & Ulrich (1977), colour indices and temperatures from Popper (1980).
- 10 Masses and radii from Popper (1982) with $i=83^\circ$ (Gadomski 1957), colour indices and temperatures from Popper (1980).
- 11 Masses and radii from Tümer *et al.* (1984), colour indices from Popper (1980) and temperatures assigned from the $B-V$ values.
- 12 Masses, radii and colour indices from Sowell *et al.* (1983), temperatures assigned from the $B-V$ values by using the Popper's calibration.
- 13 Masses, radii and temperatures from Chambliss (1976).
- 14 Masses from Popper (1982) with $i=89^\circ$ (Eaton & Hall 1979), radii and temperatures from Eaton & Hall.
- 15 Masses, radii and temperatures from Popper (1980).
- 16 Masses, radii and temperatures from Popper (1980).
- 17 Masses, radii and temperatures from Tümer *et al.* (1985).
- 18 Masses from Jakate *et al.* (1976), radii computed from these masses and the period and relative radii (R_*/a) given by Eaton & Hall (1979), temperatures from Eaton & Hall.
- 19 Masses, radii and colour indices from Vivekananda Rao & Sarma (1984), temperatures from Popper's calibration.
- 20 Masses, radii and temperatures from Andersen *et al.* (1981).
- 21 Masses and radii from Popper & Ulrich (1977), effective temperatures assigned by Naftilan (1975) by computing a synthetic spectrum of the system.
- 22 Masses and radii from Al-Naimiy (1981), temperature of the hot component assigned according to the spectral type and the Popper's calibration, temperature of the cool component computed through the ratio T_h/T_c given by Al-Naimiy.

At the top of the table the subscripts 'h' and 'c' mean 'hot' and 'cool'. Masses and radii are given in solar units and temperatures in Kelvin.

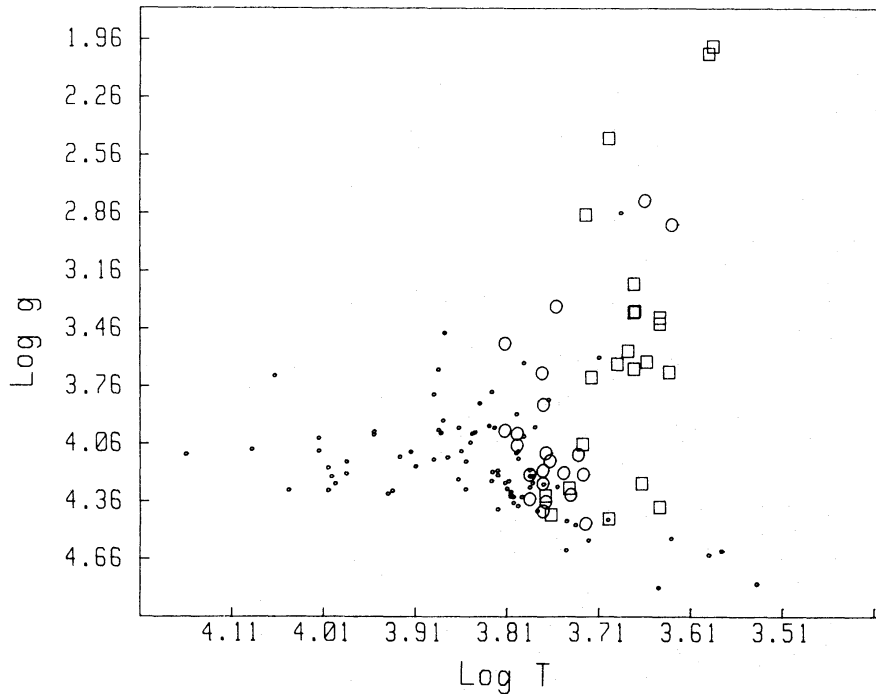


Figure 1. Log g (surface gravity) versus log T_{eff} (effective temperature) for all the stars considered in this work the sample. Circles and squares represent the hot and cool components of the RS CVn systems (Table 1). Dots are stars of the Popper list.

taken 44 detached binary stars from Popper's work (Popper 1980) covering a mass interval from 0.42 to 3.92 M_{\odot} and an effective temperature interval from 3470 to 14 450 K. We have added the evolved non-active binaries AI Phe (VandenBerg & Hrivnak 1985) and TZ For (Andersen *et al.* 1984).

From the data of Table 1 and related parameters (gravity, mass ratio, radius ratio between the components) we can extract some general properties of these systems. We have plotted in Fig. 1 the RS CVn systems (circles indicating the hot components and squares indicating the cool components) along with the normal binaries (dots) in a diagram log g versus log T_{eff} . The cool components, usually the active ones, are placed within the temperature interval 3850–5860 K (3.59–3.77 in logarithms) and the hot components have temperatures larger than 5300 K with the exception of the two giants RZ Cnc and AR Mon. The 'temperature bands' in which the hot and cool components lie are practically separated by a line around log $T_{\text{eff}} \cong 3.73$. The hot components of RZ Cnc and AR Mon lie in the 'cool band' and the cool components of UV Leo, RT And and ER Vul are in the zone of the hot components. It is remarkable to note that in the case of RZ Cnc the active star is the hot one (Hall & Kreiner 1980); for AR Mon both components show activity and UV Leo is considered by some authors as a normal low-activity pair (Koch, Plavec & Wood 1970). RT And and ER Vul do not show detectable H and K emission as we could verify by visual inspection of photographic spectra taken by members of the Departamento de Astrofísica (Universidad Complutense, Madrid), where this work was done, with the 2.2-m telescope of the German–Spanish Observatory at Calar Alto (Almeria) in 1985 August and September. TY Pyx, whose two components are near to the line log $T_{\text{eff}} \cong 3.73$, is a system in which both stars show activity.

It is necessary to indicate that the lack of non-active binary systems outside of the main sequence in the Fig. 1 is not due, obviously, to the non-existence of such systems but to the very difficult interpretation of their light curves in order to obtain absolute dimensions. This argument

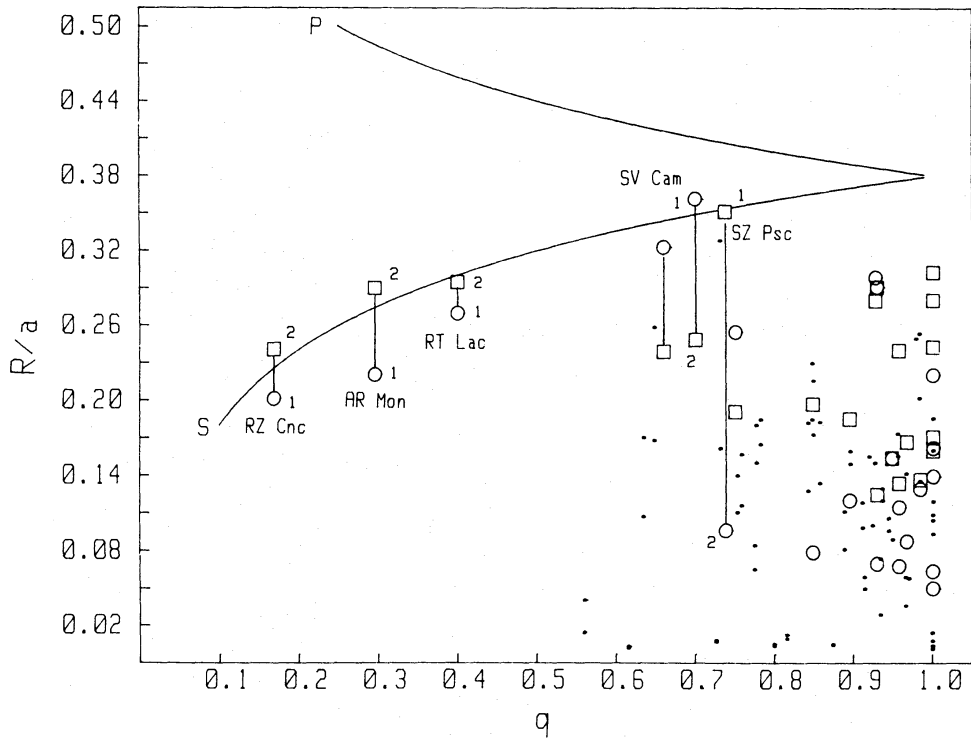


Figure 2. Plots of R/a (R : stellar radius, a : major semi-axis of the orbit) versus $q=M_2/M_1$ (subscripts 1 and 2 identify the more massive and less massive component). The lines P and S indicate, for a given q , the value of R_R/a (R_R is the radius of the Roche lobe) for the primary and secondary component, respectively. The meaning of the symbols is the same as in Fig. 1.

leads our attention towards binaries suitable for providing useful data in order to calibrate the fundamental astrophysical relationships (temperature–colour index, mass–luminosity, mass–radius, etc.).

The orbital periods, which coincide with rotation periods assuming the existence of synchronism (a reasonable argument if $P_{\text{orb}} \leq 15$ day), increase when the gravity of the more evolved component decreases. So, stars placed on, or very near to the main sequence have periods between ~ 0.6 day (SV Cam) and ~ 0.9 day (UV Psc). Another group of systems with $\log g$ between 3 and 4 have periods larger than 3.5 day with the exception of AR Lac and finally, the systems RZ Eri, RZ Cnc and AR Mon, all of them very evolved, present periods larger than 20 day.

Another important result can be seen in Fig. 2. We have plotted in this diagram a representation of R/a versus q , where R is the stellar radius, a is the major semi-axis of the orbit (a is in all the cases the distance between the centres of both stars, because the eccentricity is ~ 0 for almost all the systems), and $q=M_2/M_1$ where 1 and 2 correspond to the more massive and less massive components, which we define as the primary and secondary components. With this criterion, q is always equal to or less than 1. In the graph we have also plotted two curves labelled ‘P’ and ‘S’. If the primary (secondary) component of a system lies above the P (S) line then it is filling its Roche lobe. To draw these curves we have adopted the definition of Paczyński (1971):

$$R_R/a = 0.38 + 0.20 \log(M/M'), \quad \text{valid if } 0.3 \leq M/M' \leq 20$$

where R_R is the radius of the Roche lobe. Since we have taken in all cases $q=M_2/M_1$ less than or equal to 1, the line $0.38 - 0.20 \log q$ (P) delimits R_R/a for the more massive components and $0.38 + 0.20 \log q$ (S) is valid for the less massive components.

In three systems the secondary component fills almost absolutely the Roche lobe: RZ Cnc, AR Mon (the more evolved systems in the sample) and RT Lac. On the other hand, only in two systems are the more massive stars close to filling their Roche lobe: SV Cam and SZ Psc. It is well known that if one of the components of a binary system totally or nearly fills the Roche lobe then it is possible that phenomena related to mass exchange are present (Sahade & Wood 1978). So, at least in two of the five systems mentioned above (RT Lac and SZ Psc) some evidence of these processes has been detected.

RT Lac is a very peculiar system. According to the interpretation of the available light curves, Milone (1976, 1977) concluded that the more massive component has the lower luminosity, the later spectral type and the smaller radius. Eaton & Hall (1979), tried to find an explanation for the behaviour of the light curves by using their model of 'dark spots' on the surface of the active star. These authors estimated effective temperatures of 5300 K for the G9 component and 5715 K for the K component. This system seems to present mass flow from the cool component to the hot one (Huenemoerder 1985; Huenemoerder & Barden 1986). In the latter reference, the authors affirm that the more massive star is the coolest and smallest component of the system, in disagreement with the conclusions of Milone and Eaton & Hall. The second statement seems true but not the first one, and so, their affirmation '... the hotter component is filling 80–90 per cent of the equilibrium Roche radius...' should be changed to a similar one referring to the cool star.

SZ Psc has shown in some epochs a peculiar behaviour in the H α profiles attributed to a non-steady mass exchange regime (Bopp 1981; Huenemoerder & Ramsey 1984). Ca II monitoring of this star in 1985 (Fernández-Figueroa *et al.* 1986) showed the appearance of a transient flare-like phenomenon, probably not associated with mass exchange, suggesting that this kind of process is not always present in this binary.

The important conclusion we can extract from Fig. 2 is that practically all the RS CVn systems of our sample are detached, but this fact does not imply the impossibility of a mass transfer

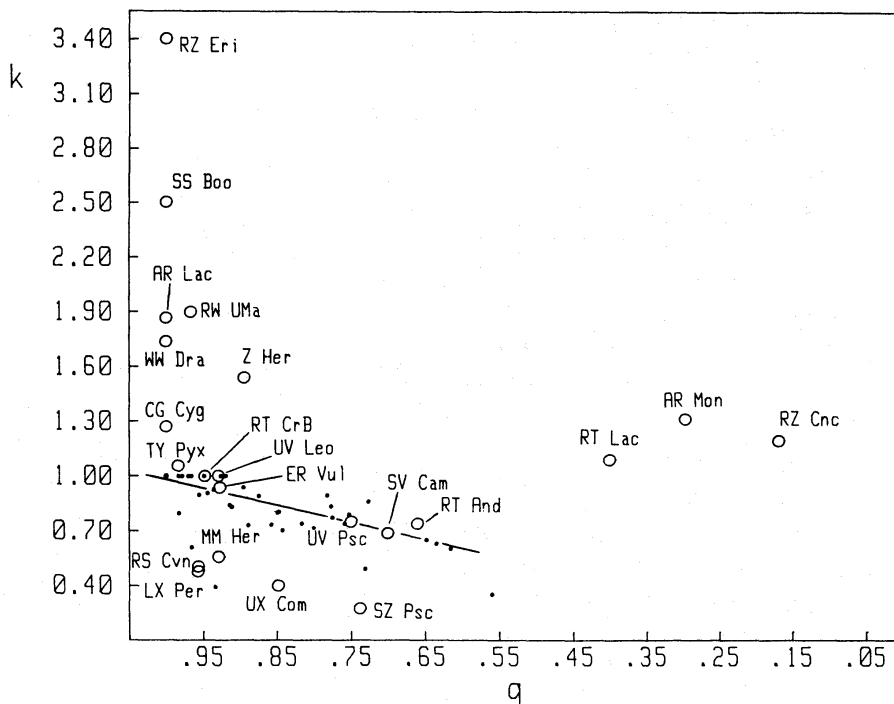


Figure 3. Plot of $k=R_2/R_1$ versus $q=M_2/M_1$. According to the position of a binary in this graph and evolutive considerations, we can divide the RS CVn sample into three different groups (see text). Here each circle or dot represents a RS CVn system or a binary of the Popper list. The straight line marks the position of the main sequence.

between the components. For instance, Webbink (1985) pointed out that a mechanism to produce mass transfer in a binary system could be the orbital contraction from orbital angular momentum losses against the well-known picture in which a component is filling its tidal lobe. In fact, in 21 of the systems studied here – the exception is UV Psc – orbital period changes, perhaps due to mass loss (Hall & Kreiner 1980), or perhaps to mass exchange, have been detected. Mass loss in binary systems leads, usually, to period increases, although there are many systems showing period decreases; the sign of the period change depends on whether it is the heavier, or the lighter, star losing mass, in the hypothesis of a mass exchange (Pringle 1985). Also, in a few cases both period increases and decreases have been observed in SS Cam, SV Cam, RS CVn, CG Cyg, RT Lac and AR Lac. Several mechanisms have been proposed to explain this behaviour, for example, apsidal motion [suggested by Hall & Kreiner (1980) for SS Cam], the presence of a third body (proposed for SV Cam by Cellino, Scaltriti & Busso 1985), anisotropic mass ejection, etc. All of them need a strong observational support to be confirmed.

In Fig. 3 we have plotted the systems in a diagram of k versus q . The definition of k is $k=R_2/R_1$ (1 and 2 have the same meaning as above). Obviously, the k values do not stay less than 1 because the more massive star does not always have the largest radius. In this graph each point represents one binary system.

Almost all of the binaries taken from Popper (1980) lie in a diagonal defining the main sequence. The normal evolution of a detached binary system involves a decrease of k , because the more massive component evolves faster than the companion and its radius increases more quickly; then the system will move towards the low part of the diagram, below the zone defining the main sequence. This standard behaviour, along with the position of the RS CVn systems, allows us to separate the stars into three groups:

- (a) *Apparently normal main-sequence stars.* This group contains RT And, SV Cam, UV Leo, UV Psc and ER Vul. For these systems the more massive component has the larger radius.
- (b) *Stars with apparently normal evolution.* UX Com, RT CrB, RS CVn, MM Her, LX Per and SZ Psc. For these systems, the more massive components have evolved faster, and their temperatures have decreased becoming the cool components of the binary. In the same place in the diagram lie the non-active evolved stars AI Phe and TZ For.
- (c) *Stars with abnormal evolution.* The evolution of these systems is abnormal in the sense that either the more massive stars have the smallest radii or components with similar masses show a large difference between their radii. The more conspicuous members of the group are RZ Cnc, AR Mon and RZ Eri. The remaining systems (SS Boo, CG Cyg, WW Dra, Z Her, AR Lac, TY Pyx and RW UMa) lie in the graph above of the main sequence. To explain the configuration of these systems it is necessary to claim the presence of a mass transfer similar to that suggested by Popper & Ulrich (1977), although in view of the parameters of some of these systems, the way followed to reach these masses, radii and temperatures is still an open question. Of course, our assertion is only qualitative and is not based on computations of stellar evolution including mass transfer.

4 Comparison with evolutionary tracks

In this section we shall make comparisons between the RS CVn systems and theoretical evolutionary tracks in order to test some aspects related with the chemical composition and the evolutionary status. Three requirements must be satisfied by a binary system to make these comparisons rigorous (VandenBerg & Hrivnak 1985):

- (i) Masses, radii, effective temperatures and metallic abundances should be known with an accuracy of ~ 5 per cent.

(ii) At least one component must be evolved, being placed far from the main sequence to allow a reliable fitting between theoretical isochrones and observational data.

(iii) There should be a significant colour difference between the components, larger than 0.1 mag, with the more evolved star redder.

In the case of most RS CVn systems the first condition is poorly satisfied; the metallic abundances are unknown and so it is not possible, for instance, to make a comparison with evolutionary tracks computed with a fixed metallicity but different helium contents in order to find lower and upper limits for the Y value in each star, in the same way as that followed by Vandenberg & Hrivnak (1985) for the binary AI Phe.

Nevertheless, if we suppose *reasonable* helium contents, around those found in the solar neighbourhood, we can give *qualitative* estimations of the metallic abundance of the RS CVn systems in our sample, by placing the stars in several evolutionary tracks with different Z values.

Table 2. Comparison of the RSCVn systems with evolutionary tracks.

System	Tracks						
	1	2	3	4	5	6	7
RT And	C	C	C	C	C	C	C
SS Boo	B	C	C	C	C	C	C
SV Cam	C	C	B	A	A	C	C
RZ Cnc	C	C	C	C	C	C	C
RS CVn	A	C	C	C	C	C	C
UX Com	C	C	C	C	C	C	C
RT CrB	C	C	C	C	C	C	C
CG Cyg	C	B?	C	C	C	C	C
WW Dra	B	C	C	C	B	C	C
RZ Eri	C	C	C	C	C	C	C
Z Her	A	C	C	C	C	C	C
MM Her	C	C	B	A	A	C	C
AR Lac	C	C	B	C	C	C	A
RT Lac	C	C	C	C	C	C	C
UV Leo	A	C	C	C	C	C	C
AR Mon	C	C	C	C	C	C	C
LX Per	C	C	C	C	B	C	A
SZ Psc	C	C	C	C	C	C	C
UV Psc	C	C	B	C	A	C	C
TY Pyx	C	C	A	C	C	C	B
RW UMa	C	C	C	B	A	C	C
ER Vul	B	C	C	A	C	C	C

The agreement between the $\text{Log } T_{\text{eff}}$ and $\text{Log } g$ values for the components of a system and their position in a given set of evolutionary tracks is indicated with the codes: A (good), B (rough), C (non-existent).

The compositions of the tracks are:

1. $Y = 0.25$	$Z = 0.017$	5. $Y = 0.25$	$Z = 0.04$
2. $Y = 0.25$	$Z = 0.003$	6. $Y = 0.20$	$Z = 0.10$
3. $Y = 0.20$	$Z = 0.04$	7. $Y = 0.30$	$Z = 0.10$
4. $Y = 0.30$	$Z = 0.04$		

We have used two sets of evolutionary tracks:

(i) Those published by Mengel *et al.* (1979) whose chemical compositions are: $Y=0.20$, $Z=0.04$; $Y=0.30$, $Z=0.04$; $Y=0.20$, $Z=0.10$; $Y=0.30$, $Z=0.10$. From the first and second tracks we have constructed an ‘average set’ with $Y=0.25$, $Z=0.04$, which has also been used.

(ii) Those published by Vandenberg (1985) with $Y=0.25$, $Z=0.017$ (solar composition) and $Y=0.25$, $Z=0.003$. This author gives tracks with lower metal contents but, as we shall see below, no system fits tracks with metallicities lower than the solar one.

In Table 2 we indicate the tracks which the binary systems fit. We have used three codes: A (good fit), B (rough fit) and C (no fit). In Figs 4–8 we show the systems placed in the evolutionary tracks $\log g$ versus $\log T_{\text{eff}}$ for which the fit is best.

With this criterion, i.e. by using several values of the He abundance, there are 13 systems whose components lie, in a coherent way, in sets of tracks with metallicity content *equal* to or *larger* than the solar one. This result is in agreement with the accepted post-main-sequence status in which are almost the whole of the systems of our sample. The remaining nine systems cannot be placed at all in the available tracks, i.e. it is impossible to get a coherent fitting of *both* components at the same time; all of them, with the exception of RT And belong to the groups (b) and (c) described in Section 3. This supports two conclusions: first, that the evolution of the components of this type of system is not as simple as the evolution of their components treated as isolated objects; secondly, that the determination of absolute parameters and, above all, effective temperatures for peculiar systems must be taken with caution and checked carefully.

According to the last conclusion, there are some results which are, *a priori*, in disagreement with our qualitative abundance estimations. Giménez *et al.* (1986) from photometric observations in the $uvby\beta$ –Strömgren system of almost all the northern RS CVn binaries, show that there is a

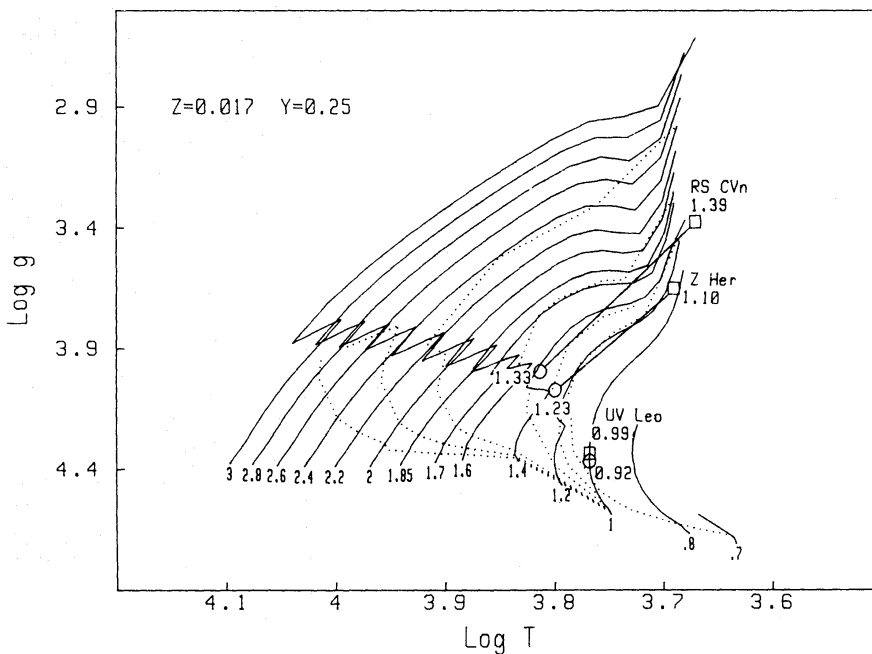


Figure 4. In this graph, and also in Figs 5–8 we show the different sets of evolutionary tracks (continuous lines) and isochronae (dotted lines) along with the RS CVn systems whose agreement between the $\log g$ and $\log T_{\text{eff}}$ values of the components and the position in the set, according to their masses, can be considered as best. We have labelled the value of the mass for each track and beside, the symbol of each component. The chemical composition is indicated in each figure.

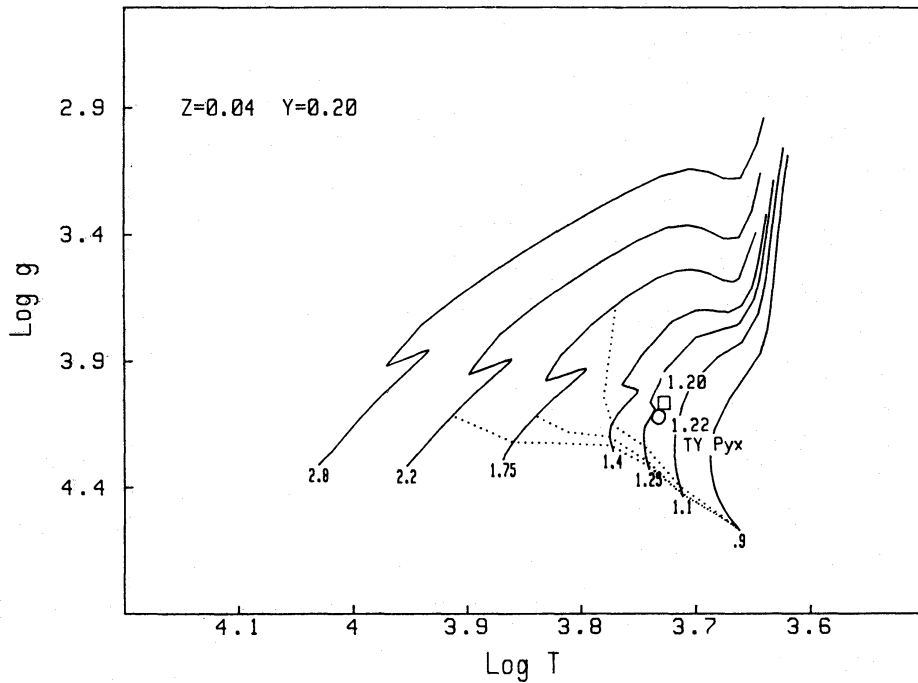


Figure 5. See caption of Fig. 4.

general trend among the active stars to have m_1 values lower than those expected from standard relationships. $m_1 = (v-b) - (b-y)$ is an indicator of peculiarity or metallicity for A stars and it gives an estimation of the chemical composition for G and F stars (Golay 1974). An excess in the δm_1 parameter [$\delta m_1 = m_1(\text{standard}) - m_1(\text{observed})$ for a given β] indicates metal underabundance in non-active main-sequence stars. Following these authors, in RSCVn systems, the observed

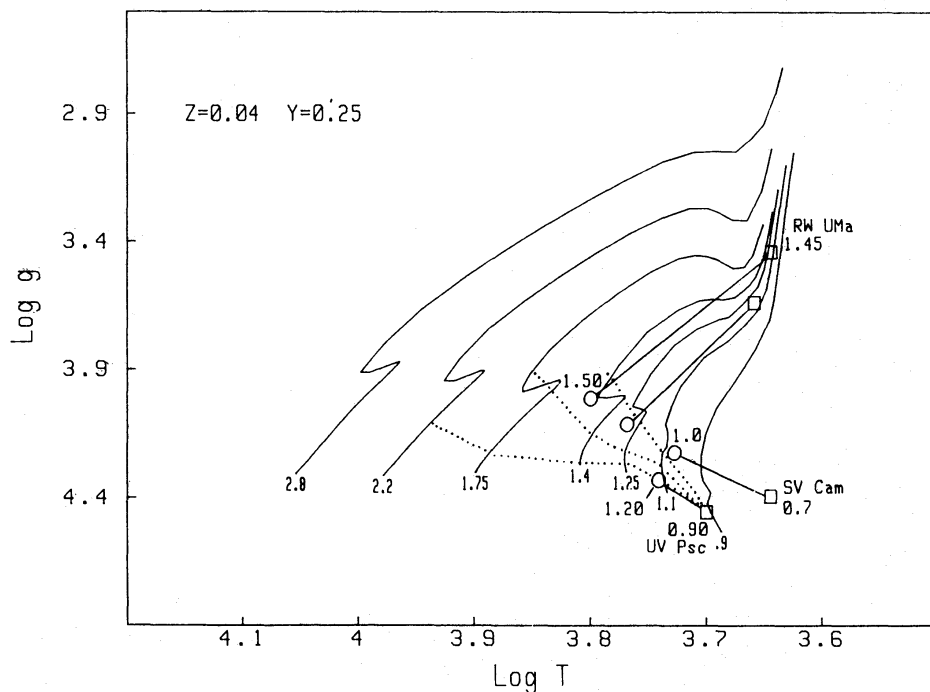


Figure 6. See caption of Fig. 4.

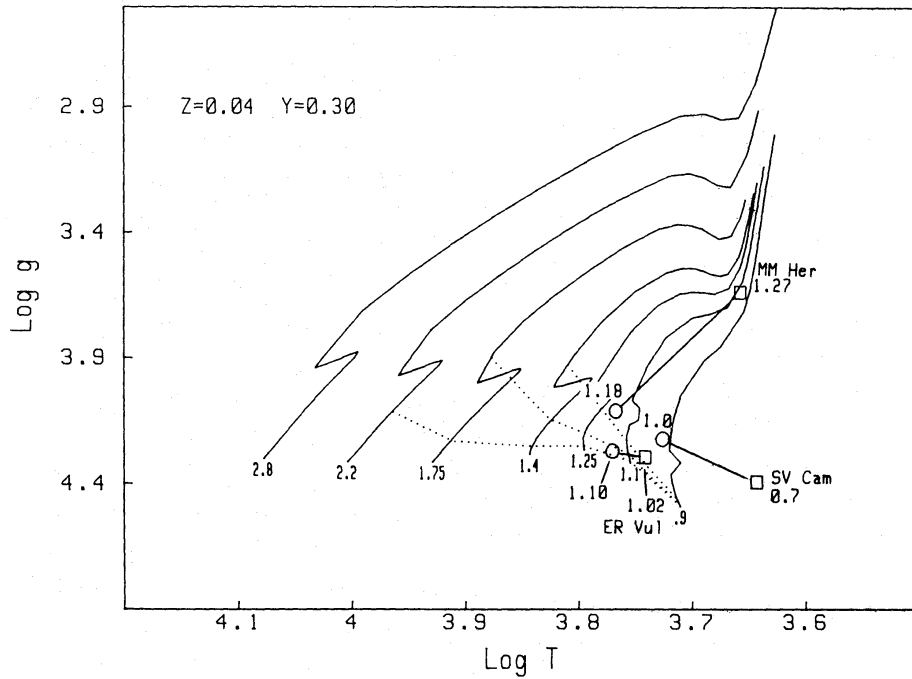


Figure 7. See caption of Fig. 4.

behaviour of δm_1 should be related to the activity degree instead of with the actual metal content. This affirmation is supported by the work of Giampapa, Worden & Gilliam (1979), who, by means of the intermediate *ubvy* system observed solar active regions in order to determine the effect of the chromospheric activity on the photometric measurements of the activity. Their results show that, applying standard calibrations, the active regions appear to be metal-deficient

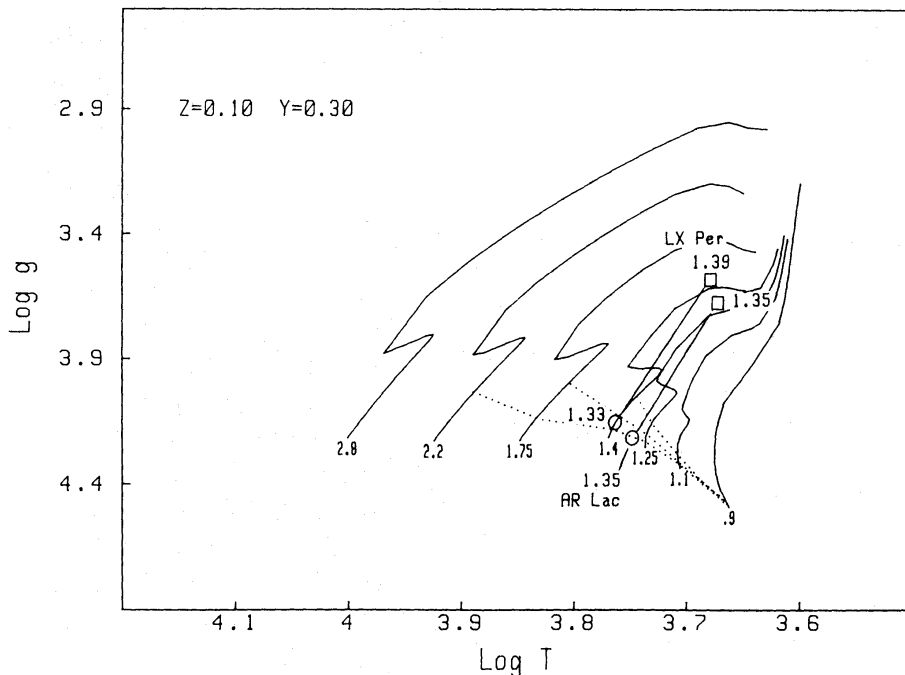


Figure 8. See caption of Fig. 4.

with respect to quiet areas by a factor of ~ 35 per cent, and therefore, by extension that there is a bias if we try to estimate photometrically the metallicity of an active star by extrapolating results found for normal stars.

Our result is also in disagreement with those presented by Naftilan & Drake (1977) for AR Lac and Naftilan (1975) and Naftilan & Drake (1980) for RS CVn. They carried out a study of the spectra of the secondary components of these two binaries and they found a deficiency in their metal content: Naftilan & Drake (1977) give $[\text{Fe}/\text{H}] = -0.70$ (spectral synthesis), -1.30 (curve of growth) for the secondary of AR Lac; Naftilan (1975) gives $[\text{Metal}/\text{H}] = -1.0$ for RS CVn and Naftilan & Drake (1980) reported $[\text{Fe}/\text{H}] = -1.9$ for the same star (adopting $\log N_{\text{H}_0} = 12$ and $\log N_{\text{Fe}_0} = 7.6$). Nevertheless, we must take into account the warning given by these authors concerning the suggestion of Rhombs & Fix (1977) about the possible existence of hot circumstellar gas surrounding the active components, leading to a weakening of the absorption lines and masking the results. Another possible explanation for the low metallicity found by these authors could be the presence of some filling in of the absorption lines similar to that appearing in active regions on the Sun which leads to metal contents lower than those computed from lines formed in non-active regions.

In any case, the general conclusion is that any result extracted for this type of star, where the atmospheric structure is little known, by using standard techniques and procedures and relationships calibrated with samples of 'normal' stars, should be taken with care.

As we can see, only the star TY Pyx fits to a set of evolutionary tracks with a Y value (0.20) that could be considered abnormal, according to the solar one, and by extension, of the helium content of the solar neighbourhood. This value is around $Y \cong 0.28$ and it has been found by many authors following different methods (Norris 1971; Nissen 1974, 1976, 1983; Keenan, Dufton & McKeith 1982; Wolff & Heasley 1985; Lebreton & Maeder 1986). It is important to point out that the comparison with evolutionary tracks is *not unique* if we do not know the metallicity, i.e. we can find agreement in the position of a star within a set of evolutionary tracks with given values of Y and Z and with another set constructed with higher (lower) Y and higher (lower) Z . Taking this fact into account and by comparison with the available set of tracks we conclude that, using a set with $Y = 0.25$, the optimum Z value for TY Pyx is around 0.07.

The remaining 12 stars fit to tracks either with $Y = 0.25$ or $Y = 0.30$, so that we can consider our estimates to be within reasonable limits.

5 Final remarks

As we have seen above, both the evolutionary status and the metallic abundance of RS CVn-like systems are, at present, open questions. To solve them, it would be desirable to have an observational effort to achieve more accurate light and radial velocity curves and spectra, in order to determine absolute parameters and abundances starting from reliable and solid observational material, and also to improve the assignments of effective temperatures from this type of special objects, taking into account the presence of dark spots on the surface of the active components.

Simultaneously there is a need for a parallel study of the abundance effects in the photometric indices and in the spectral lines used to determine the metallicity. A good knowledge of the abundance, temperatures and gravities will allow comparisons of actual parameters of the system to be made, in a more accurate way than that followed here, with different sets of evolutionary tracks to find the exact degree of evolution of each binary.

If the anomalous dimensions and properties of the systems included in the group c of Section 3 are confirmed by observations, then our attention should also be focused towards the problem of the origin of this kind of star compared with the origin of normal-evolution binaries.

The presence of activity in one or both components is an indication of the importance of internal structure phenomena (dynamo effect, movements of material due to tidal forces, etc.) which could affect the global evolution of the system.

Acknowledgments

The authors are indebted to Dr Carole Jordan for her valuable comments to clarify the content of this paper. We are also grateful to the referee, Professor J. L. Linsky, for his suggestions to improve some points of the original version. This work was carried out at the Departamento de Astrofísica of the Universidad Complutense (Madrid) and it is a part of the project 'Actividad estelar en estrellas de los últimos tipos espectrales' supported by the Spanish Comisión Asesora de Investigación Científica y Técnica (CAICYT No. 2254/83). The financial support to one of the authors (BM) with a grant of the Spanish Ministerio de Educación y Ciencia is also gratefully acknowledged.

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