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The brightness variations and orbital period changes of RT Lacertae

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Abstract. The light curves of the chromospherically active eclipsing binary RT Lacertae obtained from 1993 to 1999 are analyzed here. The variation of the brightness at mid-eclipses and at maxima is carefully re-examined. The largest variation was obtained at mid-primary, where the more massive, hotter component occults the less massive cooler secondary star. Therefore, we suggest that the variation of the system's brightness mainly arises from the more massive star. The mean brightness of the system indicates a cyclic change. It showed at least two jumps during the last 22 years. The first occurred in 1984 and the second in 1994. Therefore, the length of the magnetic cycle appears to be about ten years. All the timings of the mid-eclipses obtained so far were collected and analyzed under the assumption of the third body hypothesis. A period of 94 yr was found for the third body orbit. The variation of the systemic velocity of the eclipsing pair seems to confirm this suggestion. The time delay and advance due to the orbit of the eclipsing pair around the third component were computed and subtracted from the original residuals obtained with the linear light elements. The remaining residuals also show a quasi-periodic change. The period of this change was calculated to be about 18 yr. This second O–C change may be related to the magnetic activity of the more massive component.

Key words. stars: activity – stars: individual: RT Lac; close binary – stars: binaries: eclipsing – stars: variable: general

1. Introduction

The eclipsing binary system RT Lac is among the most peculiar stars in the Catalogue of Chromospherically Active Binary Stars (Strassmeier et al. 1993). The chromospherically active stars are often in close binary systems, most often of so-called RS CVn class. The enhanced activity in these stars is thought to be driven by strong magnetic fields arising from a dynamo mechanism connected with strong differential rotation in their convective envelopes.

Popper (1942) found double Ca II emission lines in the spectrum of RT Lac. Due to the appearance of the Ca II H and K emission lines in the spectra of both hotter and cooler stars and the finding of distorted light curves, Hall (1976) classified it as an RS CVn–type binary. It fulfils most of the Hall's criteria for intermediate-period RS CVn–type binaries. While most of this type binary has equal–mass components, the RT Lac components have unequal masses. Spectroscopic studies made by Joy (1931), Milone (1976), Huenemoerder and Barden (1986) and Popper (1991) agree that in RT Lac the more massive, which has weaker spectral lines, is in front of the less massive component at the deeper minimum. The less massive star has been referred to as G9, while the more massive one has been classified as K1. However, the colour indices $(B-V)$ and $(U-B)$ at the deeper primary minimum contradict this classification. Huenemoerder (1988), from optical and ultraviolet spectra of RT Lac, found that the hotter component contributes about 0.67 of the light of the system at λ 3000 Å and 0.33 at Hα. Moreover, the UV spectra taken at both quadratures showed strong variations in the emission line strengths, which led him to suggest that some parts of the UV emission may be produced in the impact region of a mass stream flowing from the less to the more massive component. The spectral classification of the components has been discussed in detail by Popper (1991). Later on, İbanoğlu et al. (1998a,b) examined all the light curves obtained by them during the period 1978–1992. They adopted the spectral type as G8 IV for the cooler, less massive star and assumed the existence of circumstellar matter around the binary system, which caused a colour excess of $0\overset{\mathrm{m}}{.}278$ in $B-V$. They also classified the more massive component as a G3–4 subgiant.

The strong activity in RT Lac is revealed by light curve and Hα variations, far ultraviolet emission lines (Huenemoerder & Barden 1986; Huenemoerder 1988),

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X-ray and radio emissions (Walter & Bowyer 1981; Kashyap & Drake 1999; Owen & Gibson 1978), it is therefore of high interest to monitor this peculiar system. RT Lac has been observed photoelectrically since 1978 by the authors. The purpose of this paper is to present the new BV photometry made between 1993 and 1999, and to discuss the brightness and colour changes of the system at four special phases, i.e., mid-primary, mid-secondary and at quadratures in the light curves obtained during the last twenty-two years, and derive a long term cycle in its mean brightness variation, which has already been suspected. We have also analyzed all the times of eclipses obtained so far and made some suggestions to explain the O–C changes.

2. The observations and data acquisition

The photoelectric light curves of RT Lac, presented here, were obtained annually between 1993 and 1999. All the measurements were made in the B and V passsbands of the Johnson system. A Hamamatsu R4457–type photomultiplier attached to the 48 cm Cassegrain telescope of the Ege University Observatory was used during the observations. The individual measurements were obtained differentially with respect to the BD +43° 4108 as comparison star. Its magnitude and colour transformed to the standard system have been given by Keskin et al. (1994) as $V = 7\overset{\mathrm{m}}{.}381$, $B-V = 1\overset{\mathrm{m}}{.}364$. We used BD +43° 4109 as an additional comparison star, which was observed at least four or five nights each year to check the constancy of the comparison star's light. All the differential magnitudes in the sense RT Lac minus BD +43° 4108 were corrected for differential atmospheric extinction and transformed into the standard UBV system. Using the magnitude difference between the comparison stars, we derived rms deviation of the individual measurements of ±0.006 mag for V and ±0.007 mag for B. Since the orbital period of the system changes with time, we have chosen the initial epoch from the mid–primary eclipse obtained at the beginning of each observing year to put the observations in phase.

The physical properties of the components and the parameters of the orbit are given in Table 1.

Table 1. Properties of the component stars and the parameters of the orbit

Parameter	Hotter		Cooler	Ref.
P (days)		5.074		1
i (deg)		89.7		1
$a/R_\odot$		15.842		1
$m/M_\odot$	1.582		0.624	2
$R/R_\odot$	4.44		4.78	1
log$g$	3.4		2.9	3
Spectrum	G3-4 IV[a]		G8 IV[b]	1
Te (K)	5547[a]		5167[a]	1
M_v (mag)	2.95		2.91	1

[a] Based on the colour index, [b] Assumed.

(1) İbanoğlu et al. (1998b), (2) Frasca et al. (2000), (3) Popper (1991).

3. Light curves and luminosity variations

Previous light curves have been presented and their variations discussed by İbanoğlu et al. (1980), Tunca et al. (1983), Evren et al. (1985), Evren (1989) and İbanoğlu et al. (1998a). These observations showed that both of the components of RT Lac were active. However, all the phenomena observed could not be explained by taking into account only the starspot hypothesis. Keskin et al. (1994) examined the orbital period changes and tried to derive a correlation between orbital period change and the light curve variations from the observations obtained between 1978 and 1992.

The light curves obtained between 1993 and 1999 are shown in Fig. 1. The main features of these light curves are: a) the asymmetry in the minima and the unequal maxima; b) the larger brightness variations at mid–primary than at any other phase. İbanoğlu et al. (1998b) analyzed the light curves obtained in 1984 and derived the orbital parameters of the system. Since the orbital plane is nearly perpendicular to the plane of sky and fractional radii of the components are very close to each other, the eclipses are almost total. Therefore, we may easily estimate the contribution of each component to the total light. RT Lac reaches its maximum brightness at phase 0.75, as $8\overset{\mathrm{m}}{.}706$ in V, in 1985. The brightness at mid-secondary eclipse changes between $9\overset{\mathrm{m}}{.}601$ and $9\overset{\mathrm{m}}{.}701$ in V-band. However, the brightness at mid-primary eclipse changes from $9\overset{\mathrm{m}}{.}531$ (in 1984) to $9\overset{\mathrm{m}}{.}931$ (in 1995). Therefore, fractional contribution of the hotter component to the total light of the system varies from 0.521 to 0.431 in the λ 5500 region. The maximum change in the luminosity of the cooler component is about 10 percent. However, during the same time interval, the luminosity of the hotter component changed by about 44 percent. The dramatic changes of the light curve are clearly evident when we compare the light curves obtained in 1984 and 1999 as shown in Fig. 2.

The mean brightness and colours of the system at four special phases (0.0, 0.25, 0.50, 0.75) obtained for each year are given in Table 2, and are plotted against the average observing time and are shown in Figs. 3a–d. The figures clearly show that the brightness of the system at three phases, i.e., mid-primary and quadratures, shows quasi-periodic changes. The brightness at the primary eclipse (phase 0.0) shows the largest variation with a maximum amplitude of about 0.3 mag in the B and V filter. The light variations at second maximum (phase 0.75) resemble those at primary eclipse but with a maximum amplitude of about 0.2 mag, while the variations at first maximum (phase 0.25) are generally in the opposite sense, but with a lower amplitude (about 0.1 mag). In addition, although not strictly periodic, the average cycle of the light variations is almost the same for both second maximum and primary eclipse. We estimate, from successive minima, an

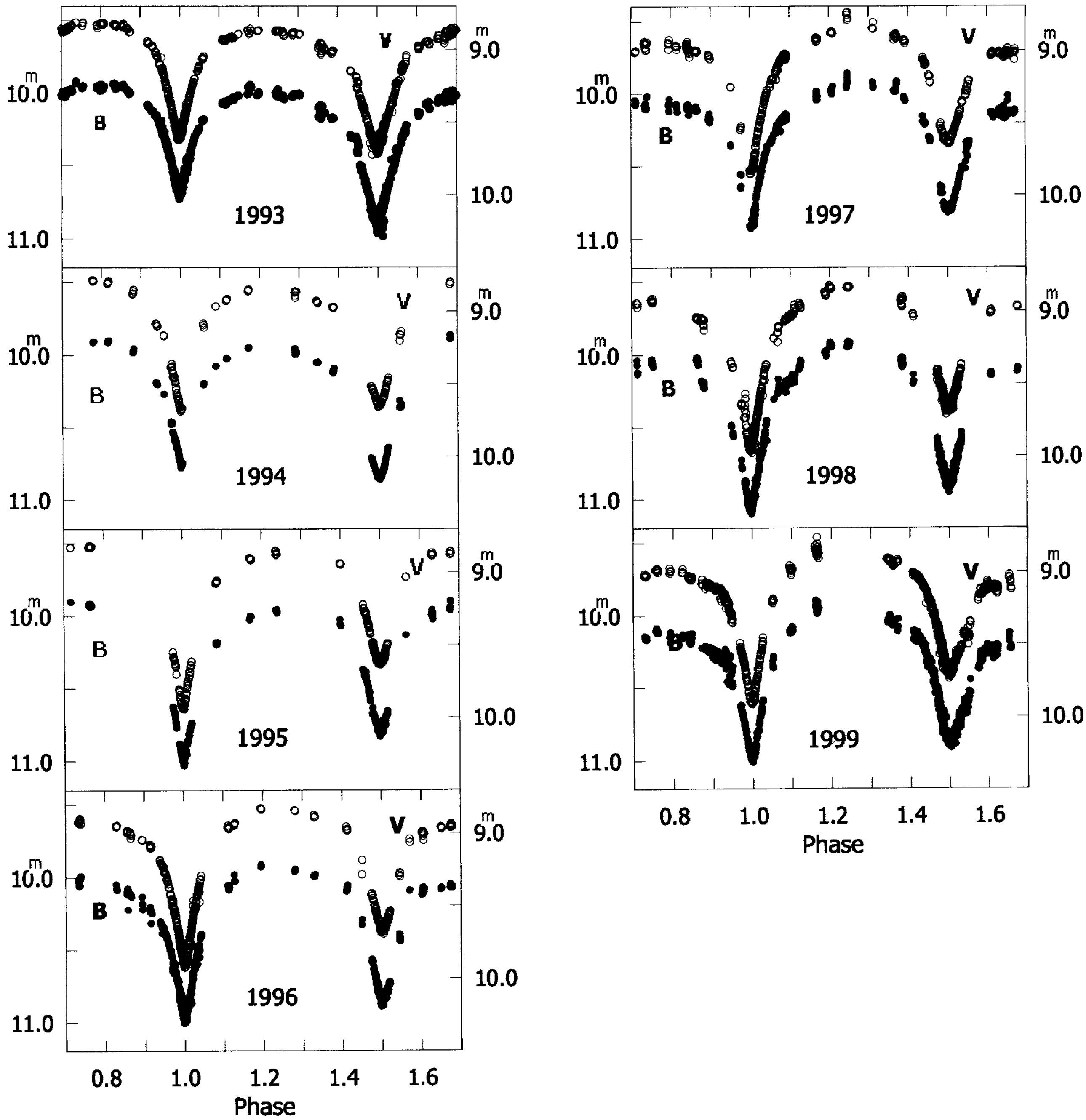

Fig. 1. The B and V light curves of RT Lac obtained annually from 1993 to 1999

average cycle of about 9–10 yr. It also appears that the brightness at mid-secondary eclipse does not display any periodic or cyclic change during the timespan of the observations. These variations clearly indicate that the main source of the light curve distortion is the more massive, hotter star which is in front of the cooler star at mid–primary eclipse. If these variations, as suggested by Eaton & Hall (1979), are due to large spot areas, the periodic variation would represent the magnetic cycle of this star.

Figures 3a–d show also that the brightness at the four special phases has been continuously decreasing. Assuming a linear decrement of the brightness, the coefficients were derived and are given in each panel. The slope of the decrement is largest at mid-primary and smallest at mid-secondary and first maximum. The brightness measured at mid–primary and at second maximum have decreased by about 0.21 and 0.18 mag, respectively, during the last 21–year time interval. On the other hand, the variations of the brightness at mid-secondary and first maximum do not exceed 0.08 mag during the same time interval, and the amplitudes of these variations seem to increase toward the longer wavelengths. The $B-V$ colour on average follow the brightness changes in the sense that the system gets bluer when it is brighter, both along the short period (cyclic) and long term variation, thus supporting the spot hypothesis. In Fig. 4, we show the variation of the

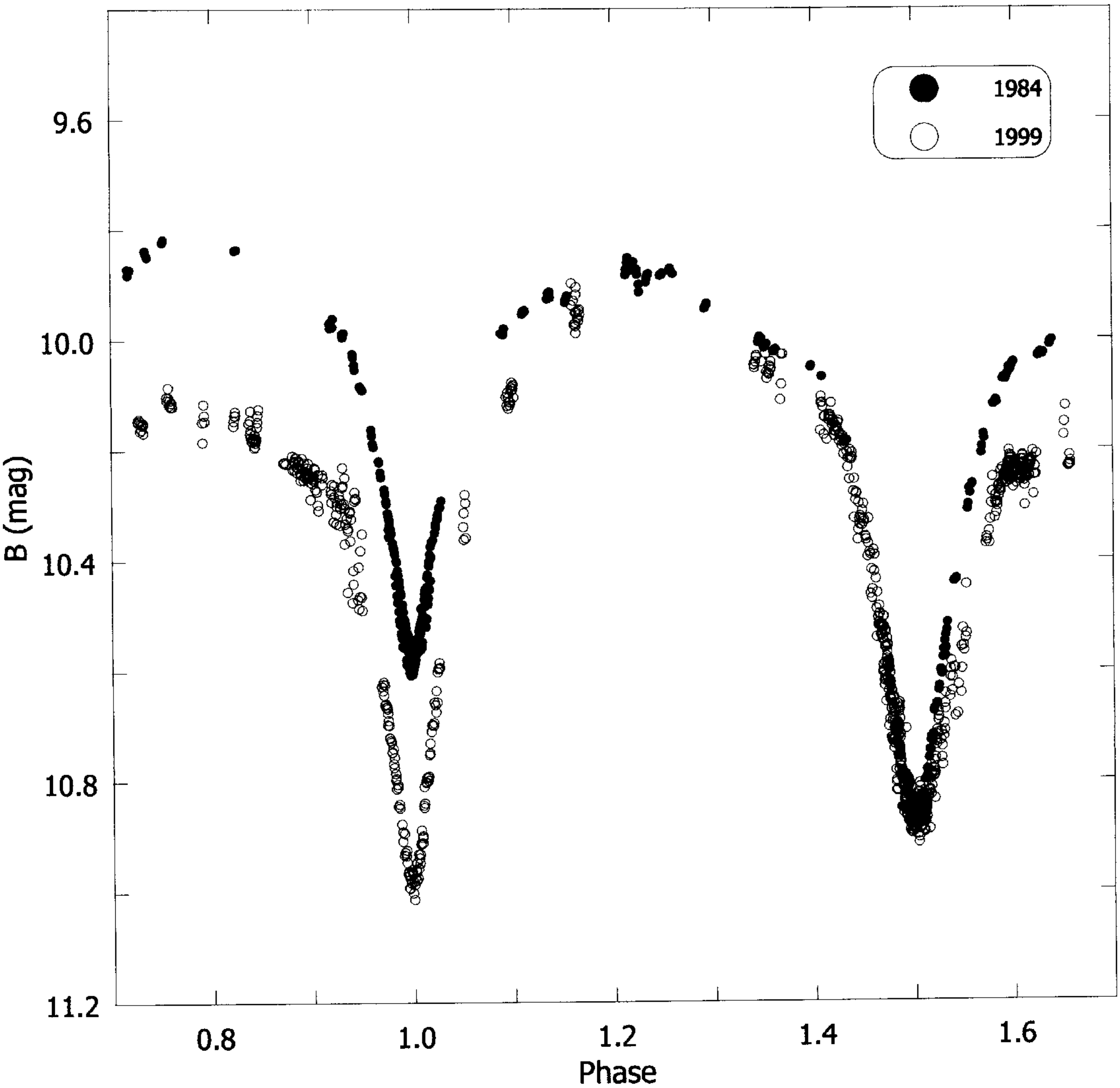

Fig. 2. The B light curves of RT Lac obtained in 1984 and 1999

average magnitude of the system, i.e., (max I + max II)/2. The average magnitude decreases slowly and jumps suddenly. The first jump is seen in 1984, the brightness then decreases up to the end of 1993. The second jump appears in 1994, and, then, the brightness slowly decreases again. The average amplitudes of these jumps are about 4 and 8 percent of a magnitude in V and B bands, respectively. This means that the average brightness of the system has increased by about 4 and 7 percent in yellow and blue light, respectively. At the bottom of Fig. 4 the mean colour, $B - V$, of the system at maxima is shown. The behaviour of the colour variation is very similar to those brightness variations. During the brightening of the system, in a ten-year time interval the colour also gets bluer. The average bluing of the system during two brightenings is about $0\overset{\mathrm{m}}{.}04$.

4. Eclipse timings and period study

All the timings of the eclipses obtained up to the beginning of 1993 were collected and published by Keskin et al. (1994). During the last eight years we obtained 14 times for primary eclipse and 13 for secondary eclipse. These new times of the minima were calculated using the method of Kwee & van Woerden (1956) and are given in Table 3 with their standard deviations. The residuals indicate the differences between the observed times of eclipses and calculated ones using the following light elements:

$$\mathrm{Min\,I} = \mathrm{JD\ (Hel)}\ 24\ 40382.8330 + 5\overset{\mathrm{d}}{.}07397688\ E.$$

Many eclipsing binaries, which contain at least one late-type convective star, show orbital period changes with time scales from a few decades to hundred years. In most

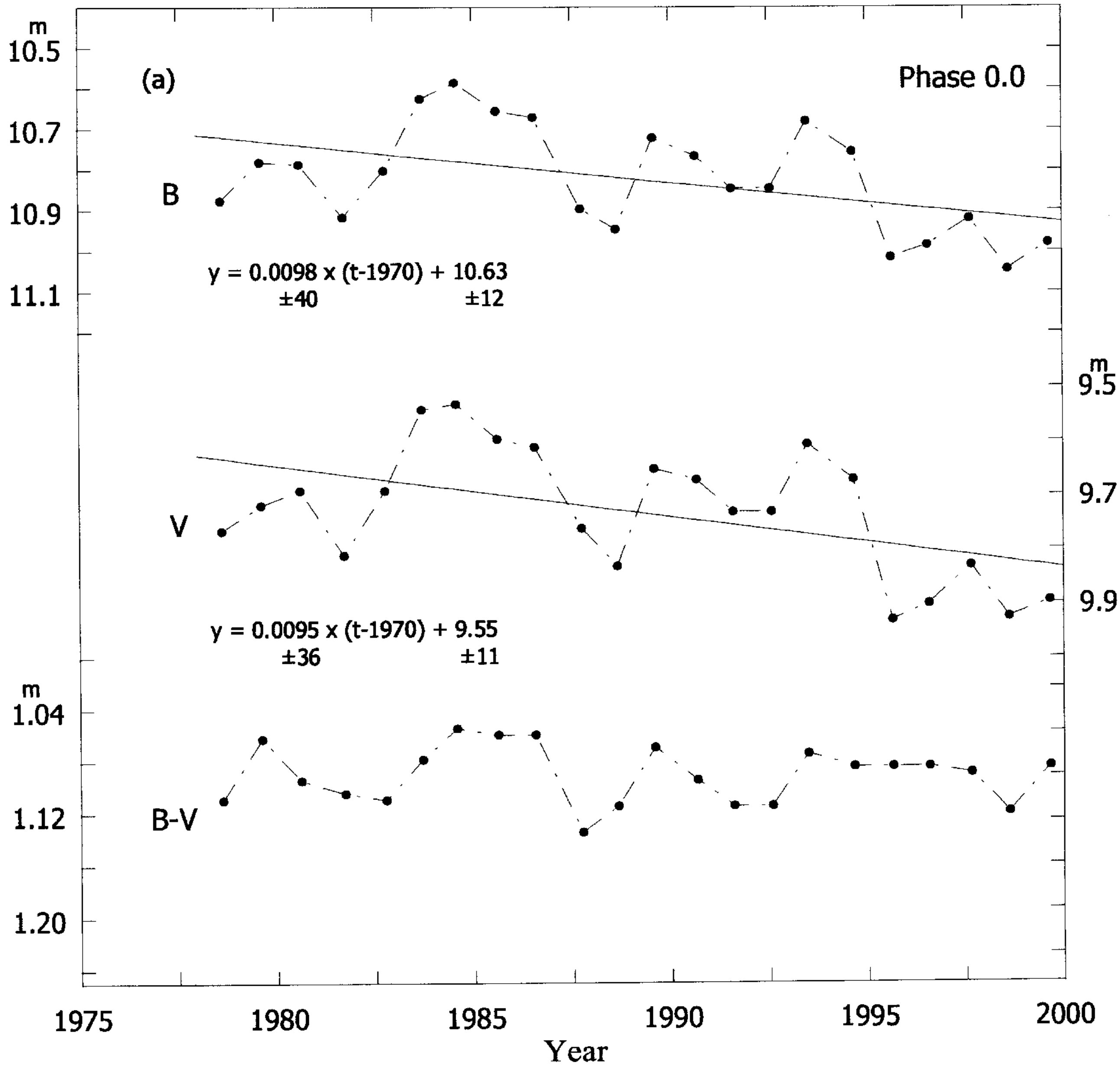

Fig. 3. a) The brightness variations at four special phases plotted against the year of measurements

of the RS CVn binaries, the orbital period decrease continuously. However, some binaries show period changes in both directions – as increase and decrease. The components of the chromospherically active close binaries are well inside their corresponding Roche lobes. Therefore, mass transfer and mass loss could not be the cause of the period changes. Hall (1990) suggested that there should be a very tight connection between orbital period changes and magnetic cycles. Applegate (1992) proposed that the orbital period changes in these binaries are a consequence of magnetic activity in one or both of the component stars. He proposed not only a mechanism which explains period changes, but suggested also a possible connection with the variations of the luminosity of the system. According to the Applegate's theory, angular momentum exchanges are accompanied by a variation of the total kinetic energy of the star. This energy is supplied by the stellar luminosity. This idea was re-examined and improved by Lanza et al. (1998a) and later by Lanza & Rodono (1999), including the effects of a magnetic field on the internal mass distribution of the active star. This model has been applied to 46 close binary systems and evidence was found that orbital period modulation is related to magnetic activity. However, they noted that there are still unsolved problems, i.e., the relationship between the lengths of activity cycles, as measured by the modulations of the spot area, and the orbital period changes. Rodono et al. (1995) found that the mean length of the starspot cycle is half that of the orbital period modulation for RS CVn. A similar result was also found by Lanza et al. (1998b) for AR Lac. While the variation of the spotted area on the secondary

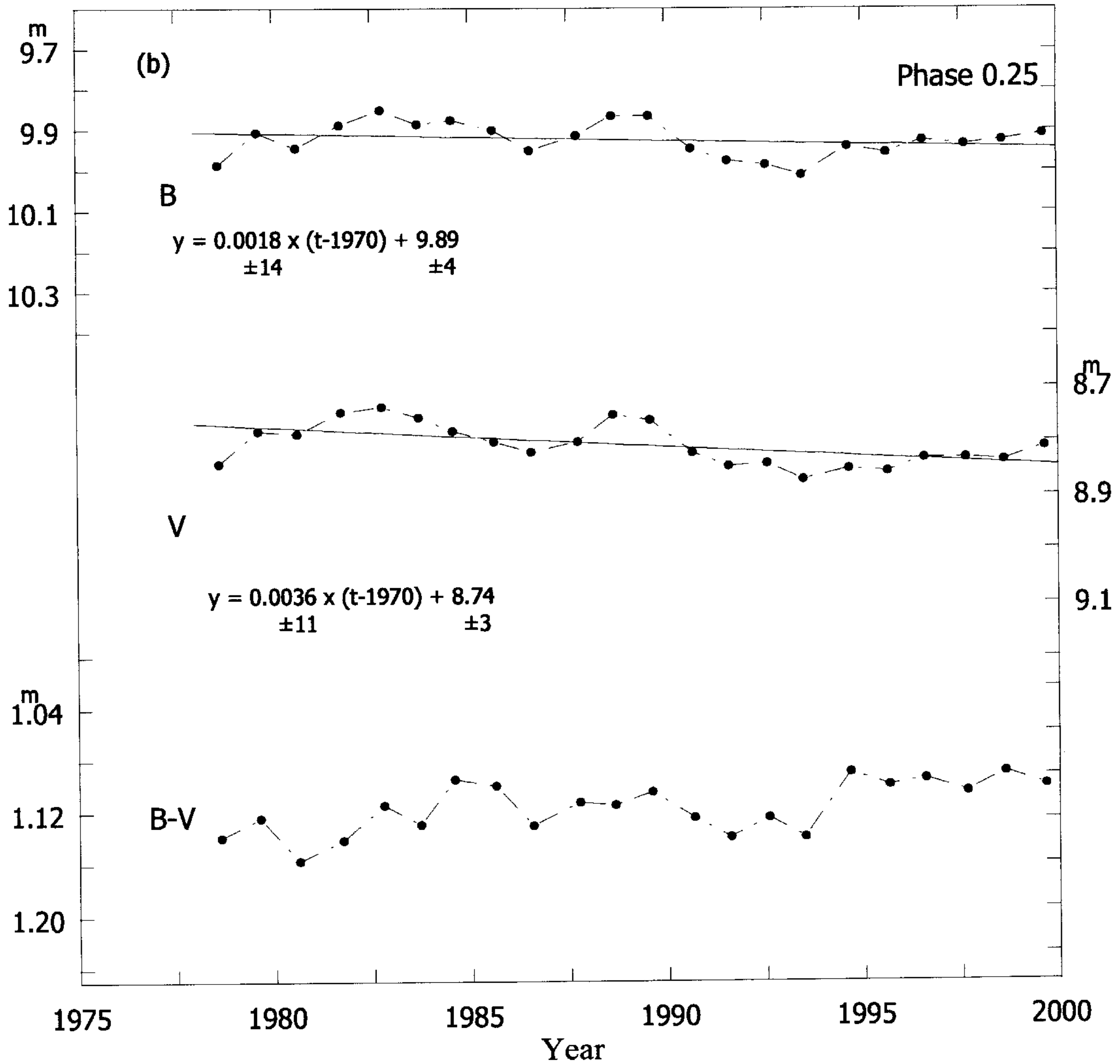

Fig. 3. b) continued

component has a cycle of about 17 yr, a period of about 35 yr was suggested for the orbital period modulation.

Keskin et al. (1994) analyzed all the available O–C residuals obtained up to 1993 by considering the light-time effect. They suggested a period of about 81 yr for the third body orbit. By subtracting the O–C changes due to the third body orbit they obtained a small amplitude sine-like change. According to their analysis, this small amplitude change was produced by magnetic activity. They suggested a period of about 12 yr for the magnetic activity in the RT Lac system.

All the timings obtained from 1890s to 2000 are re-analyzed under the hypothesis of the third body orbit. We used Mayer's (1990) definitions and equations. The weights were attributed as 10 for photoelectric timings and 1 for photographic or visual ones. By applying the weighted least squares solution we obtained the parameters for the third body orbit, listed in Table 4 with their standard deviations.

Using the $a \sin i$ of 11.3 AU and a period of 94 yr, the mass function was calculated as 0.163 $M_{\odot}$. Since the masses of the components of the eclipsing pair were recently derived by Frasca et al. (2000) as 0.624 ± 0.054 and 1.582 ± 0.069 solar masses, and the eclipsing pair orbits around the common center of mass with a period of 94 yr, the mass of the third star may be evaluated from the mass function. It depends on the inclination of the long-period orbit. Specifically, we find 1.25, 1.31 and 1.51 $M_{\odot}$ for an inclination of 90°, 75° and 60°, respectively. Thus, the minimum mass of the third star is close to that of the massive component of the binary. If such a star exists, the light curve of the system should also be affected

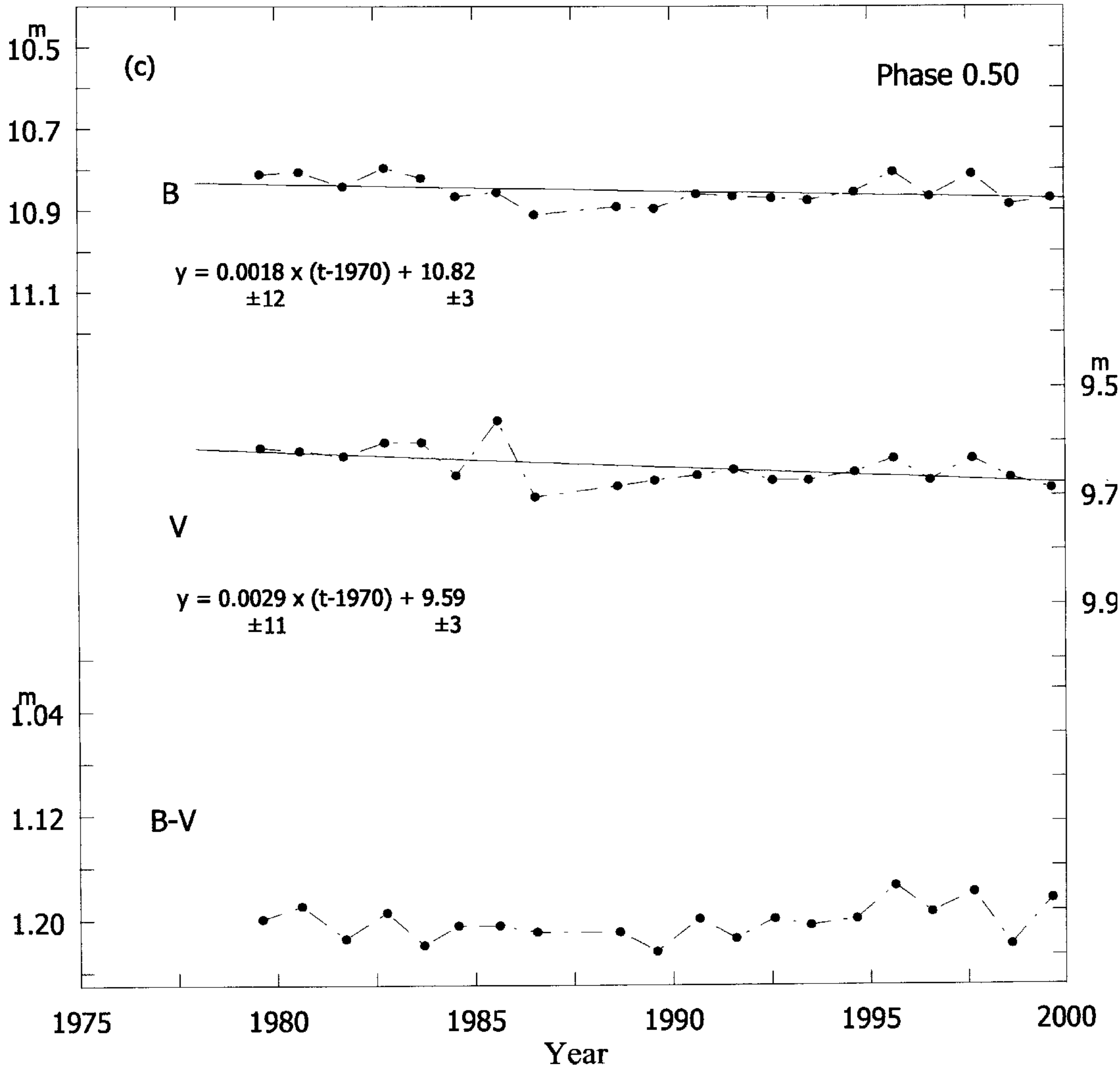

Fig. 3. c) continued

due to its contribution. However, this effect is smaller than that of magnetic activity and evaluation of the contribution of the third light from the light curve analysis seems to be very difficult.

The projected semi-major axis ($a \cos i$) of the third body around the eclipsing pair may be easily computed as 8 and 16 AU for an inclination of 75° and 60°, respectively. Then, the mean angular separation between the third star and the eclipsing pair may be calculated as 0.″042 and 0.″083 for the distance of 193 pc given in the Hipparcos catalogue. If the inclination of the orbit with respect to the plane of the sky is larger than 75°, the third body could not be angularly resolved by ground-based telescopes due to atmospheric scintillation (McAlister et al. 1993). However, if the inclination is smaller than 75°, the projected separation should be within the capability of a modern speckle interferometer on large telescopes.

The light-time effect due to orbit of the eclipsing pair around a third body has been computed with the parameters given in Table 4 and subtracted from each time of minimum and the residuals were obtained. These residuals again show a sine-like change. Assuming a periodic change and adopting the same weights for the timings, we have re-analyzed all the differences. This analysis gives a periodic change with a period of 17.8 yr and an amplitude of 0.028 days. The interference of these two changes with different origins was compared with the deviations from linear light elements in Fig. 5. We suppose that the cause of the shorter–term change in the O–C curve may be magnetic activity in one or both components of the system.

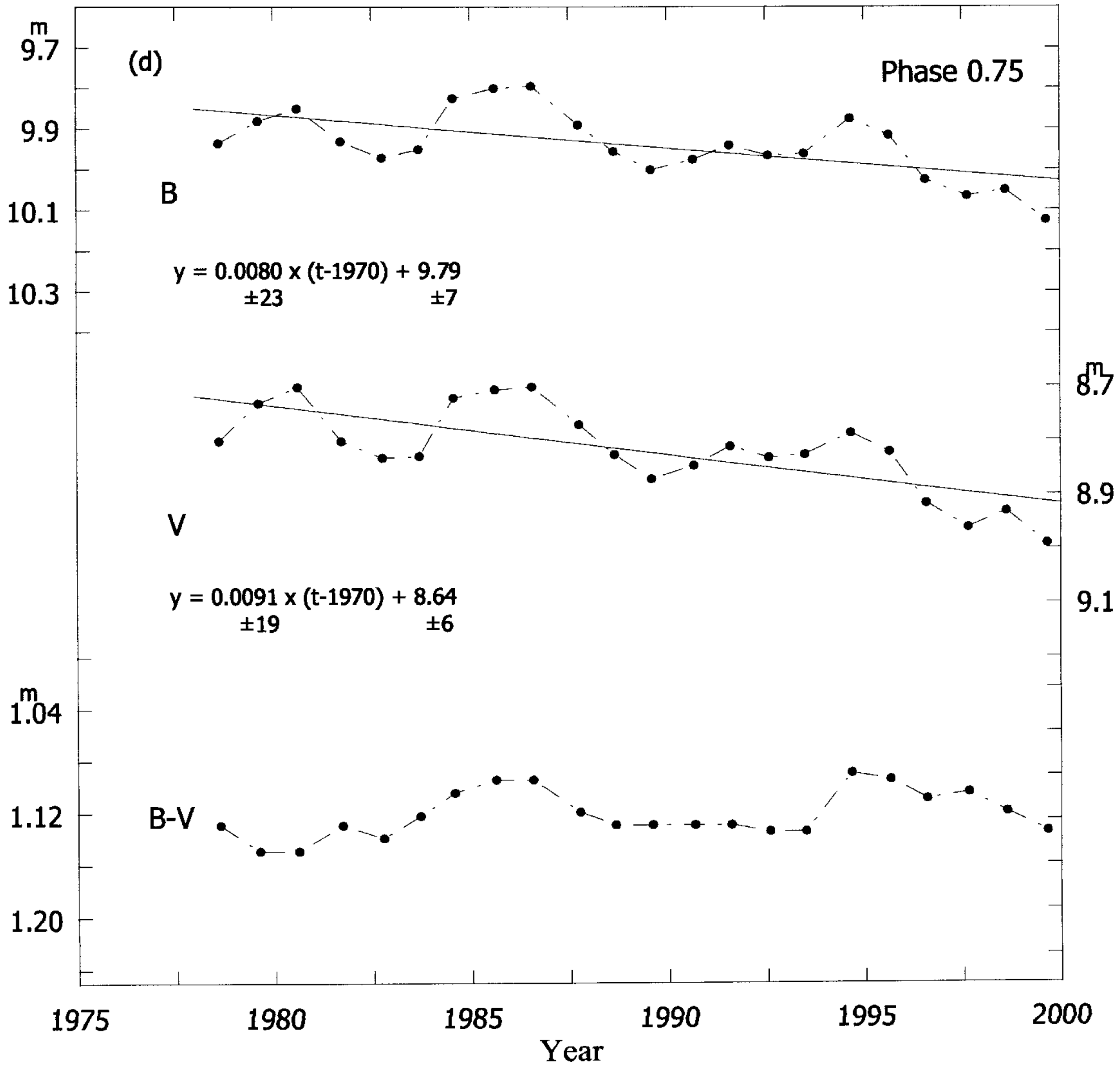

Fig. 3. d) continued

It is well known that magnetic activity in chromospherically active binaries is not periodic, as in the Sun. Therefore, if the orbital period changes are closely connected to the magnetic activity, they should not be periodic but they may display a cyclical behaviour. Since we assigned more weights for the photoelectric times of minima, the period of about 18 yr depends mainly on these.

5. Conclusions

The photoelectric observations of RT Lac, obtained between 1978 and 1999, were re-examined confirming the general behaviour of the light curve changes from year to year. In particular, the behaviour of the brightness at mid-primary, first quarter, mid-secondary and second quarter was studied in detailed. The variation of the brightness at mid-primary, which is the largest one, and at second maximum have been found to be very similar. The more massive, smaller component is in front of the less massive, larger star at mid-primary. Therefore, we can conclude, as in our previous study, that the more massive, hotter component is mostly responsible for the change in the light curve. The mean periodicity of these variations is 9–10 years and this is probably the activity cycle of this star. The absence of significant light and colour variation at the secondary eclipse, when the cooler, larger star is in front, indicates that this star does not have relevant photospheric activity. The smaller amplitude variations at the first maximum, in antiphase with that at second maximum

Table 2. The average brightness and colour of RT Lac at four special phases

	Phase 0.0		Phase 0.25		Phase 0.5		Phase 0.72	
Year	V	$B-V$	V	$B-V$	V	$B-V$	V	$B-V$
1978.62	$9\overset{\mathrm{m}}{.}766$	$1\overset{\mathrm{m}}{.}109$	$8\overset{\mathrm{m}}{.}841$	$1\overset{\mathrm{m}}{.}139$	-	-	$8\overset{\mathrm{m}}{.}801$	$1\overset{\mathrm{m}}{.}129$
1979.62	9.718	1.062	8.781	1.124	9.611	1.199	8.731	1.149
1980.61	9.691	1.094	8.786	1.157	9.616	1.189	8.701	1.149
1981.72	9.811	1.104	8.746	1.141	9.626	1.214	8.801	1.129
1982.76	9.691	1.109	8.736	1.114	9.601	1.194	8.831	1.139
1983.70	9.541	1.078	8.756	1.129	9.601	1.219	8.828	1.122
1984.57	9.531	1.054	8.781	1.094	9.661	1.204	8.721	1.104
1985.62	9.596	1.059	8.801	1.099	9.561	1.204	8.706	1.094
1986.56	9.611	1.059	8.820	1.130	9.701	1.209	8.701	1.094
1987.75	9.761	1.134	8.801	1.112	-	-	8.771	1.119
1988.65	9.831	1.114	8.751	1.114	9.681	1.209	8.826	1.129
1989.59	9.651	1.069	8.761	1.104	9.671	1.224	8.871	1.129
1990.67	9.671	1.094	8.821	1.124	9.661	1.199	8.846	1.129
1991.59	9.731	1.114	8.846	1.139	9.651	1.214	8.811	1.129
1992.57	9.731	1.114	8.841	1.124	9.671	1.199	8.831	1.134
1993.49	9.606	1.074	8.871	1.139	9.671	1.204	8.826	1.134
1994.65	9.671	1.084	8.851	1.089	9.656	1.199	8.786	1.089
1995.64	9.931	1.084	8.856	1.099	9.631	1.174	8.821	1.094
1996.57	9.901	1.084	8.831	1.094	9.671	1.194	8.916	1.109
1997.64	9.831	1.089	8.831	1.104	9.631	1.179	8.961	1.104
1998.61	9.926	1.119	8.836	1.089	9.666	1.219	8.931	1.119
1999.65	9.896	1.084	8.811	1.099	9.686	1.184	8.991	1.134

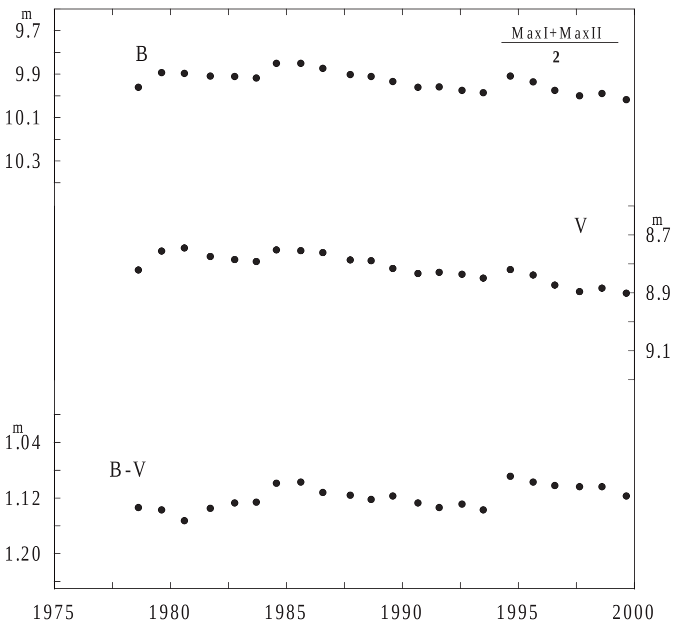

Fig. 4. The variation of the average magnitude of the system with time

and primary minimum, suggest that the spotted region is mainly concentrated on the hemisphere of the hotter component visible at the primary minimum and at the second maximum. The antiphase variation is consistent with a migration of the spots on the surface of the hot star with a period of about 6 years, but it does not explain why the decrease in the light is greater when spots occur near the second maximum. At the maximum light, the first and second maximum have about the same brightness, while at the minimum light the second maximum reaches fainter magnitudes.

When we examine the behaviour of the mean brightness (average magnitude at both maxima) of the system we encounter an interesting situation. The average brightness of the system is decreasing continuously. During the last 22 years the average brightness has decreased by about $0\overset{\mathrm{m}}{.}2$ (see Fig. 4). However, the larger brightness decreases occur at primary eclipse and at second maximum, the magnitude at second eclipse remaining nearly constant. This indicates a long–term change in the hotter component, that may be due to an increase in the spot coverage on a longer cycle. However, the brightness jumped up suddenly in 1984 and 1994. These jumps are also seen in the colour of the system. When the system is brighter, the colour becomes bluer. This ten-year period may correspond to the magnetic activity cycle of the active component of RT Lac.

The new times for mid-primary and secondary eclipses obtained by us were added to previously published data and the differences from the linear light elements were analyzed. Since the O–C residuals for both eclipses show a periodic change with time, first the light-time orbit was taken into account. The weighted least squares solution gave the parameters of the third body orbit. Then, the residuals were computed for each observing time using the parameters of the third body orbit and subtracted from all the residuals. The remaining differences showed a periodic change with a small amplitude. The amplitude and period of this change were computed using a least squares fit. Combining these two effects, the O–C values were recomputed and compared with the observed ones.

Table 3. Timings for primary and secondary eclipses

JD (Hel.) (24 00000+)	E	O–C (I) (day)	Filter	JD (Hel.) (24 00000+)	E (day)	O–C (I)	Filter	JD (Hel.) (24 00000+)	E (day)	O–C (I)	Filter
49168.4055 ±16	1731.5	−0.0185	V	49924.4189 ±29	1880.5	−0.0276	B	51365.4330 ±17	2164.5	−0.0230	V
49201.3809 ±14	1738.0	−0.0239	B	49929.4937 ±14	1881.5	−0.0268	B	51365.4337 ±18	2164.5	−0.0223	R
49201.3854 ±13	1738.0	−0.0194	V	49929.4940 ±17	1881.5	−0.0265	V	51464.3603 ±21	2184.0	−0.0382	B
49206.4561 ±17	1739.0	−0.0227	V	49957.4069 ±21	1887.0	−0.0205	V	51464.3613 ±24	2184.0	−0.0372	V
49206.4575 ±16	1739.0	−0.0213	B	49957.4086 ±20	1887.0	−0.0188	B	51464.3612 ±27	2184.0	−0.0373	V
49239.4307 ±18	1745.5	−0.0289	B	50269.4578 ±17	1948.5	−0.0192	V	51738.3540 ±13	2238.0	−0.0393	R
49239.4327 ±18	1745.5	−0.0269	V	50269.4610 ±14	1948.5	−0.0160	B	51738.3580 ±17	2238.0	−0.0353	B
49244.5064 ±10	1746.5	−0.0272	B	50297.3630 ±17	1954.0	−0.0208	V	51738.3600 ±14	2238.0	−0.0333	V
49244.5071 ±10	1746.5	−0.0265	V	50297.3637 ±19	1954.0	−0.0201	B	51743.4267 ±19	2239.0	−0.0405	V
49546.4116 ±19	1806.0	−0.0237	B	50302.4333 ±31	1955.0	−0.0245	B	51743.4275 ±26	2239.0	−0.0397	B
49546.4119 ±24	1806.0	−0.0234	V	50302.4378 ±33	1955.0	−0.0200	V	51743.4275 ±27	2239.0	−0.0397	R
49551.4837 ±29	1807.0	−0.0255	V	50675.3853 ±41	2028.5	−0.0098	B	51781.4925 ±24	2246.5	−0.0296	B
49551.4844 ±28	1807.0	−0.0248	B	50675.3881 ±39	2028.5	−0.0070	V	51781.4950 ±31	2246.5	−0.0271	R
49579.3898 ±37	1812.5	−0.0263	V	51025.4859 ±18	2097.5	−0.0136	V	51781.4967 ±19	2246.5	−0.0254	V
49579.3905 ±39	1812.5	−0.0256	B	51025.4865 ±21	2097.5	−0.0130	B	51814.4576 ±27	2253.0	−0.0453	R
49584.4605 ±27	1813.5	−0.0296	B	51053.3775 ±29	2103.0	−0.0289	B	51814.4611 ±21	2253.0	−0.0418	V
49584.4667 ±29	1813.5	−0.0234	V	51053.3798 ±21	2103.0	−0.0266	V	51814.4649 ±20	2253.0	−0.0380	B
49612.3633 ±33	1819.0	−0.0337	B	51091.4477 ±27	2110.5	−0.0135	B	51870.2738 ±18	2264.0	−0.0429	B
49612.3730 ±31	1819.0	−0.0240	V	51091.4407 ±19	2110.5	−0.0205	V	51870.2754 ±19	2264.0	−0.0413	V
49924.4157 ±21	1880.5	−0.0308	V	51365.4313 ±18	2164.5	−0.0247	B				

This analysis shows that the eclipsing pair revolves around a third star with a period of about 94 years. We estimated a mass for the third star of 1.25 and 1.51 $M_{\odot}$ for orbital inclinations of 90° and 60°, respectively. Due to the orbit of the eclipsing pair around the third body, its γ velocity should change periodically with an amplitude of about 8 km s^{-1}. However, at least four systemic velocities of the eclipsing pair were obtained from 1931 to 2000. The systemic velocity of the binary system was obtained as −47, −52, −54 and −58 km s^{-1} by Joy (1931), Popper (1991, observing time is late 1969), Huenemoerder & Barden (1986) and Frasca et al. (2000), respectively. These measurements approximately refer to the years 1924, 1969, 1984 and 2000, thus indicating a steady increase in the absolute baricentric velocity, at variance with the values expected for an orbital motion with a period of 94 years. The errors reported for the gamma values by the various authors are in the range of 1–2 km s^{-1} and therefore, the measured change in the systemic velocity is larger than 3σ, indicating a significant baricentric acceleration. These changes would confirm the existence of a third star, dynamically bound to the binary, but eventually with a longer orbital period.

Table 4. Parameters of the third body orbit

Parameter	Value	Standard deviation
$a_{12} \sin i$ (km)	$1.691\,10^{9}$	$0.336\,10^{9}$
e	0.42	0.02
ω (deg)	174	4
T_3 (day)	JD 11902	665
P_3 (yr)	94	1.6
T_1 (day)	40382.8330	0.0023
P_1 (day)	5.07397688	$1.09\,10^{-6}$
A (day)	0.1185	0.0019
f(m) ($M_{\odot}$)	0.163	0.093

If one assumes an inclination of about 75° for the orbit of the third body around the binary, a projected

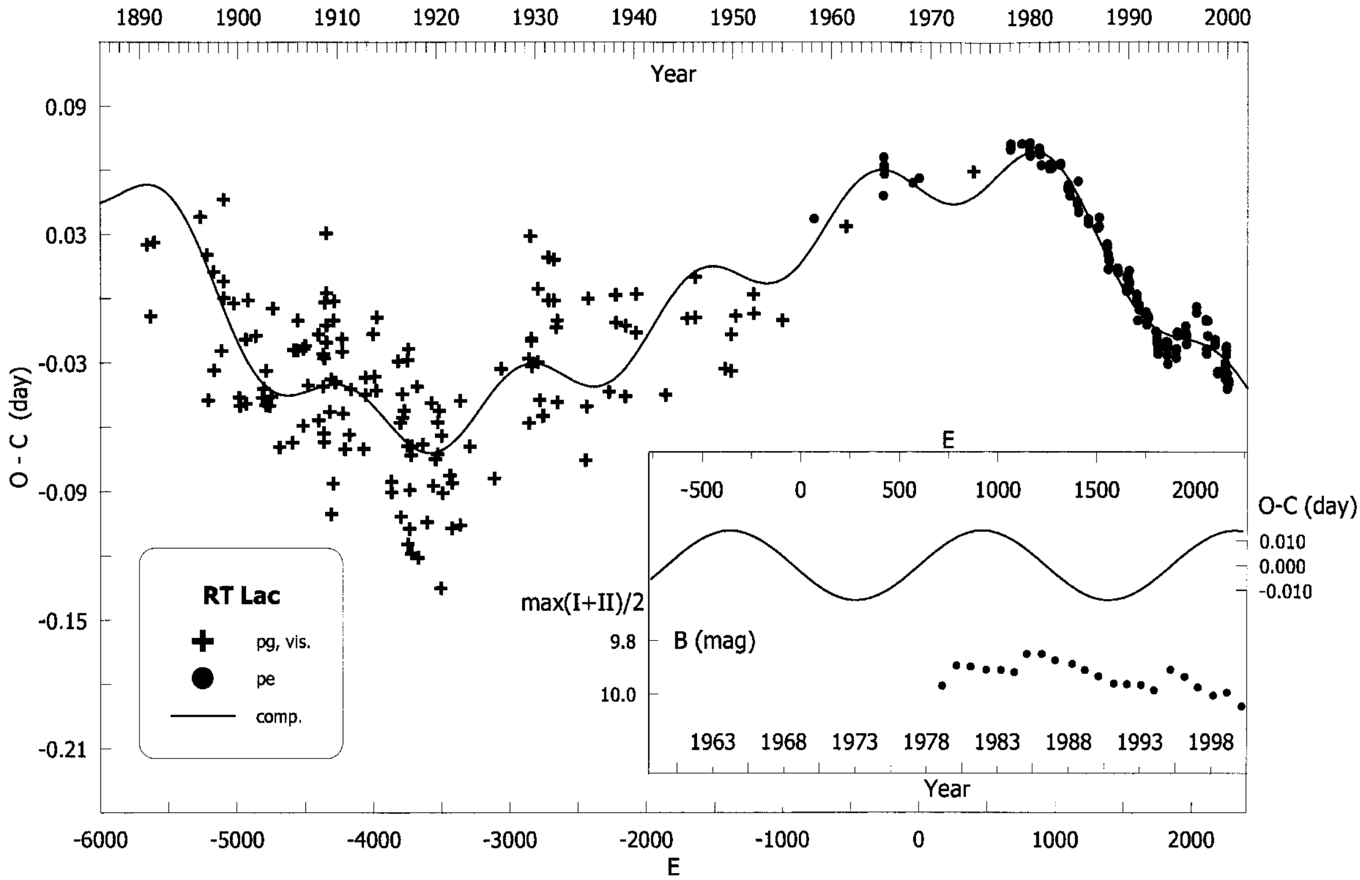

Fig. 5. Residuals for all the times of minimum light of RT Lac with respect to the linear light elements. The continuous curve represents the interference of the light-time effect and a small amplitude, small period change which was attributed to the magnetic activity. At the lower-right panel, the mean brightness of the system at the maxima and small amplitude orbital period change supposedly originating from the magnetic activity are shown

semi-major axis of about 8 AU is obtained. Since the distance of the system is about 193 pc, the semi-major axis of the orbit should be about 0.″04. The oscillatory proper motion of the binary should then be observable when a suitably long sequence of astrometric positions will be available.

The small amplitude, short period O–C changes were attributed to the magnetic activity. The length of the magnetic cycle was estimated to be about ten years from the variations in the brightness. However, if the small amplitude O–C changes originated from the magnetic activity, its period should be very close to the magnetic cycle of the active component. In the case of RT Lac, the cycle length of the period change is close to twice the period estimated from the luminosity variation. It is interesting to note that a spot cycle with a period of half that of the orbital period modulation has been reported for RS CVn and AR Lac, as mentioned in the previous section. It is surprising that during the second jump of the system's brightness the orbital period started to increase. The orbital period increased from 1994 to 1997 and decreased again. A similar behaviour is also seen in 1964. However, such a change in the period of the system was not noticed in 1984.

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