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BV photometry and Hα spectroscopy of the RS Canum Venaticorum binary V711 Tauri

S. Mohin and A.V. Raveendran

Indian Institute of Astrophysics, Bangalore - 560034, India

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Abstract. — Differential *BV* photometry of V711 Tau obtained on a total of 120 nights during the years 1984-91 and Hα spectroscopy obtained on 14 nights during the 1990-91 observing season are presented. We find that the mean light level of the system during the period 1975-82 was fainter by ~ 0.05 mag than that during the period 1982-91. The change in the mean light level probably arises from a global reduction in the area of spots or from the disappearance of spots from the polar region. At larger amplitudes the brightness at minimum decreases and the brightness at maximum increases, both converging to a particular value of ΔV at very low amplitudes. Phase of light minima observed during 1975-91 lie on two independent near-straight lines, implying that spots are confined predominantly to two different latitude belts. The Hα equivalent widths did not show any orbital modulation during the period of our observations. The spectra obtained on one night (1991 Feb. 6) show a sudden drop in equivalent width; this occurs during the descending branch of the light curve.

Key words: photometry — spectroscopic binary — V711 Tau

1. Introduction

The RS Canum Venaticorum binary V711 Tau (= HR 1099) is one of the brightest members ($V \sim 5.7$ mag) of its class and probably the most frequently observed at wide wavelength regions. It is a non-eclipsing, double-lined spectroscopic binary (K1 IV + G5 V) with an orbital period ~ 2.84 days (Bopp & Fekel 1976; Fekel 1983). V711 Tau is known as a strong and variable radio source (Owen et al. 1976) and also as a source of strong radio bursts (see the series of papers in *Astronomical Journal* 83, No. 12, 1978). In addition to the radio emission, V711 Tau is found to emit both soft and hard X-rays (Walter et al. 1978; White et al. 1978). Chromospheric and transition region emission lines, implying stellar surface fluxes of up to several hundred times the typical solar values, have been detected in the ultraviolet with IUE (Linsky 1984 and references therein). The ultraviolet observations indicate the presence of compact active regions.

Vogt & Penrod (1983) applied the Doppler Imaging Technique for the first time to V711 Tau in order to determine the position of photospheric spots and bright chromospheric regions by exploiting its high rotational velocity and fairly certain orbital inclination ($v \sin i \approx 40$ km s^{-1} and $i \approx 33°$, Fekel 1983). Later Gondoin (1986) applied the same technique to photospheric absorption lines (Fe I) and chromospheric emission lines (Ca II IR and Hα) and found that on the surface of the primary both photospheric spots and bright solar-like chromospheric plages overlap. He also found that the location and extent of the active centres suggest the existence of strong magnetic flux at relatively high latitudes, $\sim 60°$.

Ramsey & Nations (1980) have spectroscopically established the existence of cool starspots, using 8860 Å TiO band observations. Spectroscopic studies by several investigators (Simon & Linsky 1980; Fraquelli 1984; Nations & Ramsey 1986; Buzasi et al. 1991) have indicated evidences of strong, variable, and short-term Hα activity in V711 Tau.

Photometric observations of V711 Tau have been carried out by many investigators (Mekkaden et al. 1982; Bartolini et al. 1983; Rodono et al. 1986; Strassmeier et al. 1989 and references therein). We observed V711 Tau as part of an on-going long-term photometric programme of RS CVn systems and related objects. In this paper we present *BV* photometry obtained during the years 1984-91 and Hα spectroscopy obtained during the 1990-91 observing season, and discuss the results.

2. Observations and data reduction

2.1. BV photometry

V711 Tau was observed photometrically on a total of 120 nights during the seven Observing seasons 1984-85 (10 nights), 1985-86 (8 nights), 1986-87 (30 nights), 1987-88 (25 nights), 1988-89 (10 nights), 1989-90 (14 nights) and 1990-91 (23 nights) with the 34-cm reflector of Vainu Bappu observatory, Kavalur (VBO) using standard B and V filters. The visual companion ADS 2644B (K3 V) was included in all the measurements. The observations were made differentially with respect to the comparison star 10 Tau (= HR 1101) and were transformed to the Johnson's UBV system. Table 1 gives the differential magnitudes and colours for the variable in the sense V711 Tau minus 10 Tau. The unpublished individual observations obtained during 1981-82 season (Mohin et al. 1982) are also given in Table 1. The typical uncertainty in the measurements of the differential magnitudes and colours is ~ 0.01 mag. Each value in Table 1 is a mean of three to four independent measurements.

To convert the Julian days of observation into orbital phases we have used the ephemeris of Bopp & Fekel (1976),

$$JD\ (\text{hel.}) = 2442766.069 + 2\overset{\text{d}}{.}83782\ E.$$

The zero phase corresponds to conjunction with the more active K-subgiant in front and the period is the spectroscopic orbital period.

2.2. Hα observations

Hα region spectra of V711 Tau were obtained on a total of 14 nights during the 1990-91 observing season, near simultaneously with the photometry obtained during that season. Observations were made with the Zeiss Cassegrain 102-cm telescope of the VBO using Carl-Zeiss Universal Astronomical Grating Spectrograph (UAGS) with a Bausch and Lomb 1800 lines mm^{-1} grating blazed at 5000 Å in the first order. The detector used was a Thomson-CSF TH 7882 CCD chip coated for enhanced sensitivity to ultraviolet radiation and mounted in a liquid-nitrogen-cooled dewar. The data acquisition was done using a "Photometrics CCD system" supplied by Photometrics Ltd., U.S.A. The UAGS setup with a 250-mm Schmidt camera gives a dispersion of ≈ 0.50 Å per pixel at Hα region. The slit width was set to give a projected width of around two pixels. Wavelength calibrations were carried out using a Fe-Ne hollow cathode tube.

The spectroscopic data were analysed on a VAX 11/780 computer using the interactive package RESPECT developed locally at VBO (Prabhu & Anupama 1991). The spectrum extraction procedures in RESPECT are based on optimal extraction algorithm discussed by Horne (1986). Only observations with a signal to noise ratio $S/N \sim 100$ were included in the analysis. The integration times ranged from 30 to 45 minutes for these spectra. All the spectra were normalized to the continuum level defined in each spectrum by a straight line fit to the relatively line-free stable points. The resolution employed in the present observations is not good enough for a detailed profile analysis and hence we have concentrated our efforts only on the equivalent width measurements. V711 Tau being a non-eclipsing binary, the equivalent width of the underlying Hα absorption profile, arising from the photospheres of both the components, is independent of orbital phase.

Two different estimates of Hα equivalent widths have been made from the programme star spectra; the first (denoted by EW1) was obtained by integrating the Hα emission profile above the continuum, and the second (denoted by EW2, cf. Fraquelli 1984) by subtracting the area below the continuum from the area above the continuum in the fixed wavelength interval $\lambda\lambda$ 6550-6580.

In order to estimate the errors in the measurement of equivalent widths, a few standard stars of late spectral types were also observed on several nights. The equivalent widths EW2 obtained for these objects show that the method entails an uncertainty of $\sim$ 0.2 Å. In both cases EW1 and EW2, the wavelengths for the integration were visually set on the computer monitor. To ascertain the consistency of the method independent measurements were made on the same spectra, and the measured EWs did not differ by more than 0.05 Å.

Table 2 gives the log of observations; it contains Julian day of observation along with Hα emission equivalent width (EW1), full width at half maximum of Hα emission (FWHM), height of the Hα emission in terms of F_λ/F_c, photometric phase reckoned from the ephemeris of Bopp & Fekel (1976), and the equivalent width EW2.

3. Discussion

3.1. Light curves

The V observations presented in Table 1 are plotted in Fig. 1 which also contains the mean epochs of observation. The $B-V$ observations show that there is no significant correlation of the colour with the light variation.

The photometric properties derived from the present observations together with those compiled from various sources are listed in Table 3. For a few light curves which show a reasonably sinusoidal nature the phases of the light minima were determined by fitting the truncated Fourier series,

$$L = A_0 + A_1 \cos\theta + A_2 \cos 2\theta + B_1 \sin\theta + B_2 \sin 2\theta,$$

where θ is the photometric phase, and A_0, A_1, A_2, B_1 and B_2 are the Fourier coefficients. For other light curves the light minima were taken from the respective graphs. The amplitude of the light variation given in Table 3 is the difference between the values of $\Delta V_{\max}$ and $\Delta V_{\min}$, the brightness at light maximum and minimum.

3.2. Mean light level

In Fig. 2 we have plotted the mean light level of the system calculated from

$$\text{mean } \Delta V = (\Delta V_{\max} + \Delta V_{\min})\,/2$$

against the corresponding mean epoch of observations. It is interesting to see from the diagram that the mean light level of the system during the period 1975-82 was fainter by ~ 0.05 mag than that during the period 1982-91. It can be seen that this change in the mean light level of the system occurred during a very short period. Observations obtained around the epoch 1981.91 show a mean brightness of $\sim$ 1.55 mag, whereas those obtained around the epoch 1982.08 indicate a mean brightness $\sim$ 1.47 mag (Mohin et al. 1982; Rodono et al. 1986). Here we note that the mean quiescent *uv* emission level of V711 Tau observed around the epoch 1983 was higher than that observed at earlier epochs. For example the CIV emission line flux observed in 1983 was 30 % more than that observed in 1978 (Anrews et al. 1988). The variation in mean light level during 1982-91 was more erratic when compared to that during 1975-82. The change in the mean light level probably arises from a global reduction in the area of spots or from the disappearence of spots from the polar region.

3.3. Brightness at light maximum and minimum

From an analysis of the brightness at light maximum and minimum, based on the then available data, Mekkaden et al. (1982) found that the brightness of V711 Tau at light minimum is nearly constant and that an increase in the amplitude is directly related to an increase in the brightness at light maximum. From this they argued that the hemisphere of the active component visible at light minimum is always saturated with spots and that an increase in the amplitude of light variation is a consequence of the disappearance of spots from the hemisphere visible at light maximum. Later from more extended observations Bartolini et al. (1983) found that in V711 Tau the brightness at both light maximum and light minimum is variable.

In the light of the results presented in Fig. 2, we have divided the data into two groups representing two different periods, one covering from 1975-81 and the other from 1982-91, and in Fig. 3 we have plotted the $\Delta V_{\max}$ and $\Delta V_{\min}$ against the corresponding amplitudes for the two periods.

An inspection of the top panel of Fig. 3 reveals that at larger amplitudes the brightness at minimum decreases and the brightness at maximum increases and both of them converge to $\Delta V \sim 1.55$ mag at very low amplitudes as seen in the case of UX Ari (Mohin & Raveendran 1989). This indicates, qualitatively, the following as already suggested by Bartolini et al. (1983): (i) At lower amplitudes spots are evenly distributed in longitudes and are predominantly present at higher latitudes and hence are seen through out the rotational period. (ii) At higher amplitudes spots are more concentrated about some longitude and are predominantly at lower latitudes and hence disappear from the field of view during the rotational period. Probably there was no substantial change in the total spotted area on the surface of the star during the period 1975-81 since the gain or loss in $\Delta V_{\max}$ is more or less compensated by the same amount in $\Delta V_{\min}$ when the amplitude increases or decreases.

The dataset for 1982-91 (bottom panel of Fig. 3) is limited, making it difficult to draw firm conclusions. The increase in $\Delta V_{\max}$ with increase in amplitude of the light curve is very obvious, whereas the variation in $\Delta V_{\min}$ with the amplitude is not that apparent; in fact $\Delta V_{\min}$ appears to be more or less constant with a mean value of $\sim \Delta V = 1.52$ mag. Most likely, the situation here is similar to what Mekkaden et al. (1982) faced in their analysis from a limited data series.

3.4. Phase of light minimum and amplitude

The evolution of starspots in RS CVn systems is usually analysed from the temporal behaviour of the phase of light minimum ($\phi_{\min}$) and amplitude of light variation. We have plotted the $\phi_{\min}$ and V amplitude given in Table 3 against the corresponding mean epoch of observation in Figs. 4 and 5 respectively. The phases of shallow minima are indicated by open circles in Fig. 4.

The minimum (identified as group A) first observed in 1975 can be traced to about 1981 nearly continuously. Just before this minimum disappeared (or became less prominent) almost in the opposite longitude another centre of activity (group B) was formed; this could be traced upto about 1985 unambiguously. On most occasions during the period 1986-90 two light minima could be identified in the light curves. It appears that one group of minima is a continuation of the minimum (group B) seen from 1981 onwards, and the other group lies close to the positions expected if the minimum (group A) observed first observed in 1975 had continued. Group B has a slope close to zero indicating that the corresponding photometric period is very close to the assumed orbital period. The migration of the other minima is a result of the difference in the photometric and orbital periods. The migration of the minima seen during 1975-80 indicates a rotation period of 2.84007 ± 0.00009 days (continuous line), and when we include the minima seen after 1986 also we arrive at a photometric period of 2.84036 ± 0.00005 days (dotted line). The shallow minima are not included in the least square solutions.

The minima observed around 1984-85 which occur $\sim 0\overset{p}{.}4$ and plotted as part of group B (indicated by arrows in Fig. 4) could be part of the group A minima as well. The presence of single minima in the light curve does not necessarily imply that there is only one centre of activity. It indicates only the longitude of the predominant spot group. The light curve obtained during 1986-87 shows two minima, one $\sim 0\overset{p}{.}5$ and the other $\sim 0\overset{p}{.}8$, whereas the next season's light curve shows only one minimum centred $\sim 0\overset{p}{.}43$. The brightness at the light maximum of the later light curve is nearly the same as the brightness at the light minimum at $0\overset{p}{.}8$ of the former light curve.

The two groups of minima lie on two independent near-straight lines, implying that spots are confined predominantly to two different latitude belts. It is likely that the centre of activity corresponding to the minimum first observed in 1975 (group A), probably with varying extent of spots, has continued to exist at least till the last observing season. This indicates a life span of more than 15 years for the centre of activity. If it had ceased to exist in between, say after about 1982, then the appearence of light minima after 1986 close to the positions expected from an extrapolation of earlier positions would mean the reappearance at the initial longitude of occurrence implying a prefered longitude also.

From the results of Doppler Imaging Techniques applied to UX Ari, Vogt & Hatzes (1991) have argued that the equatorial regions in the active component are synchronized to the orbital motion and that higher latitudes rotate faster than the equatorial regions, contrary to what is observed in the sun. The photometric period for group B is close to the orbital period indicating near synchronization at the latitude corresponding to that spot group. For the other group the period is larger than the orbital period indicating a slower rotation. If the results obtained for UX Ari hold in the case of V711 Tau, we would expect the photometric period to be either equal to or less than the orbital period. In the case of V711 Tau the photometric results do not indicate that there are latitudes which rotate faster than the synchronous latitudes, and that if equatorial regions are synchronized higher latitude regions rotate slower than the equatorial regions.

Amplitude of the light curve is an important parameter which reflects the longitudinal distribution of spots. The changes in the amplitude can result either from (i) a change in the size of the spot and its temperature, or (ii) due to a longitudinal redistribution of the spots on the stellar surface, or (iii) due to the occurrence of spots at sufficiently high latitudes, so that they are always visible as the star rotates. An inspection of Fig. 5 reveals that the light curve amplitudes are highly variable and show a cyclic behaviour with a period of about 3 years. It is also found that substantial changes in the amplitude can occur in as short as a few orbital cycles. The change from larger to smaller amplitude is followed at times with the appearance of two minima. The largest amplitude so far observed was during 1979 when the system's $\Delta V_{\rm min}$ was also at its minimum value reported to date. The highest $\Delta V_{\rm max}$ observed so far is 1.364 mag (during the 1985-86 period). The $\Delta V_{\rm max}$ observed during 1979 was 1.44 mag, considerably fainter than the highest $\Delta V_{\rm max}$ observed so far, indicating that spots were present on the projected stellar disc at all phases and did not disappear even at the epoch of the highest amplitude so far observed.

3.5. Hα observations

The Hα observations show that the emission is variable and there is no correlation either with the photometric or with the orbital phases. The average values of EW1 and FWHM are ≈ 0.87 Å and ≈ 3.66 Å respectively and are comparable to the mean values obtained by Bopp & Talcott (1978) from the observations spanning a rather long period, 1975-78. They found that the variation in equivalent width is ≈ 50% over intervals of several days and it is probably not related to flare events. The mean equivalent width obtained by them is ≈ 0.8 Å.

The equivalent width of Hα emission appears to be uncorrelated with either the amplitude, or $\Delta V_{\rm max}$, or $\Delta V_{\rm min}$ of the light curves. The light curve during 1975-78 is quite normal with an amplitude about 0.10 mag, with $\Delta V_{\rm max}$ about 1.50 mag and $\Delta V_{\rm min}$ about 1.60 mag, where as 1990-91 light curve shows a smaller amplitude of 0.075 mag with $\Delta V_{\rm max}$ and $\Delta V_{\rm min}$ of 1.484 and 1.559 mag respectively. The average values of the Hα emission EW and FWHM obtained by Nations & Ramsey (1986) during 1981 (Mar, Sept, Oct and Nov) shows 1.2 Å and 3.9 Å respectively. The light curve obtained during this period shows an amplitude about 0.10 mag with $\Delta V_{\rm max}$ about 1.50 mag and $\Delta V_{\rm min}$ about 1.60. The mean light level of the system during 1990-91 observing season is brighter by about 0.03 mag than that during the years 1975-78 and year 1981.

If the extensive starspot activity on the surface of the active component is analogous to what is observed in the sun, then a strong correlation is expected between the chromospheric activity and the light variability. If Hα emission is highly localized on the cooler and active star in the system, then it should show a modulation with the rotational period of the star. The Hα spectroscopic studies by Bopp & Talcott (1978) do not indicate any such modulation. But observations by Nations & Ramsey (1980) and Ramsey & Nations (1980) indicate some evidence of a modulation of Hα emission equivalent width with the photometric phase. Fracquelli (1984) has argued that both stars in the system show Hα in emission and the primary contributes ≈ 70 % of the total emission, with the secondary star producing the remaining 30 % emission. Nations & Ramsey (1986) have used the refined ephemeris of Fekel (1983) and have argued that the primary is responsible for 86 % of the total emission.

It is evident from the spectra obtained on the same night that significant changes in equivalent width occur on time scales as short as a few hours (Table 2). the Hα equivalent widths EW1 and EW2 listed in Table 2 are plotted in Fig. 6 along with the light curve obtained during the same period. We see from Fig. 6 that apparently there is no correlation between the light curve and the equivalent widths EW1 and EW2, and that there is no modulation of these with orbital phase. However EW1 observations obtained on one night (1991 Feb. 6) show a sudden drop which occurs during the descending branch of the light curve. This change is not of instrumental origin, since the standard star spectra obtained on that night show a scatter of only ~ 5 %. These observations indicate that the location of Hα emitting region is not highly localized, but occupies a large extent of the surface area on the active component of the system. However, the IUE observations of V711 Tau indicate more compact active regions that are presumably magnetic in origin, analogous to the solar-like active areas (Rodono et al. 1987; Andrews et al. 1988).

4. Conclusions

We have presented the differential *BV* photometry of V711 Tau obtained on a total of 120 nights during the years 1984-91 and Hα spectroscopy obtained on 14 nights during the 1990-91 observing season. The mean light level of the system during the period 1982-91 was brighter by ~ 0.05 mag when compared to that during the period 1975-82. Probably there was a corresponding change in the mean quiescent *uv* emission level also.

The behaviour of brightness at light maximum $\Delta V_{\max}$ and brightness at light minimum $\Delta V_{\min}$ in relation to the amplitude of light variation has been analysed. At larger amplitudes $\Delta V_{\min}$ decreases and $\Delta V_{\max}$ increases; both converge to a particular value of ΔV at very low amplitudes. In terms of the starspot model this implies the following: (i) At lower amplitudes spots are evenly distributed in longitudes and are predominantly present at higher latitudes and hence are seen through out the rotational period. (ii) At higher amplitudes spots are more concentrated about some longitude and are predominantly located at lower latitudes and hence disappear from the field of view during the rotational period.

In the case of V711 Tau the spots are, most likely, confined predominantly to two different latitude belts as indicated by the grouping of the phases of light minima on two independent near-straight lines. The lifetime for a spot forming region is found to be more than 15 years.

Though the Hα emission strengths are highly variable, V711 Tau does not show any modulation of the same with the orbital phase during the period of our observations. However spectra obtained on one night (1991 Feb. 6) show a sudden drop in equivalent width which occurs during the descending branch of the light curve. The present observations do not indicate a strong relationship between the spot activity implied by the light curve and chromospheric activity implied by the Hα emission equivalent width. Simultaneous multiwavelength coordinated observations, well distributed in rotational phases spread over many observing seasons are needed in determining whether spots and active regions are spatially correlated.

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References

Andrews A.D., Rodono M., Linsky J.L. et al. 1988, A&A 204, 177

Bartolini C., Guarnieri A., Piccioni A. et al. 1978, AJ 83, 1510

Bartolini C., Blanco S., Catalano M. et al. 1983, A&A 117, 149

Bopp B.W., Fekel F.C. 1976, AJ 81, 771

Bopp B.W., Espenak F., Hall D.S. et al. 1977, AJ 82, 47

Bopp B.W., Talcott J.C. 1978, AJ 83, 1517

Buzasi D., Ramsey L.W., Huenemoerder D.P. 1991, The Johns Hopkins Univ. Maryland, preprint, No. 88

Chambliss C.R., Hall D.S., Landis H.J. et al. 1978, AJ 83, 1514

Chambliss C.R., Detterline P.J. 1979, Inf. Bull. Var. Stars, No. 1591

Cutispoto G. 1990, A&A Suppl. 84, 397

Fekel F.C. 1983, ApJ 268, 274

Fraquelli D.A. 1984, ApJ 276, 243

Gondoin P. 1986, A&A 160, 73

Horne K. 1986, PASP 98, 609

Landis H.J., Lovell L.P., Hall D.S. et al. 1978, AJ 83, 176

Linsky J.L. 1984, in Cool Stars, Stellar Systems and the Sun (eds: Baliunas S.L., Hartmann L.) Springer-Verlag, p. 244

Mekkaden M.V., Raveendran A.V., Mohin S. 1982, JA&A 3, 27

Mekkaden M.V. 1987, Inf. Bull. Var. Stars, No. 3043

Mohin S., Raveendran A.V., Mekkaden M.V. et al. 1982, Inf. Bull. Var. Stars, No. 2190

Mohin S., Raveendran A.V. 1989, JA&A 10, 35

Nations H.L., Ramsey L.W. 1980, AJ 85, 1086

Nations H.L., Ramsey L.W. 1986, AJ 92, 1403

Owen F.N., Jones T.W., Gibson D.M. 1976, ApJ 210, L27

Parthasarathy M., Raveendran A.V., Mekkaden M.V. 1981, Astrophys. Space. Sci. 74, 87

Parthasarathy M., Raveendran A.V., Mekkaden M.V. 1981, Astrophys. Space. Sci. 74, 87

Prabhu T.P., Anupama G.C. 1991, Bull. Astr. Soc. India 19, 97

Ramsey L.W., Nations H.L. 1980, ApJ 239, L121

Rodono M., Cutispoto G., Pazzani V. et al. 1986, A&A 165, 135

Sarma M.B.K., Ausekar B.D. 1980, Acta Astr. 30, 101

Sarma M.B.K., Ausekar B.D. 1981, Acta Astr. 31, 103

Simon T., Linsky J.L. 1980, ApJ 241, 759

Strassmeier K.G., Hall D.S., Boyd L.J., Genet R.M. 1989, ApJ. Suppl. 69, 141

Vogt S.S., Penrod G.D. 1983, PASP 95, 565

Vogt S.S., Hatzes A.P. 1991, in IAU Coll. No. 130 (eds: Moss T.D., Rudiger G.) Springer-Verlag, p. 297

Walter F.M., Charles P., Bowyer S. 1978, Nat 274, 569

White N.E., Sanford P.W., Weiler E.J. 1978, Nat 274, 569

Table 1. The differential magnitudes and colours of V711 Tau

J.D. (Hel) 2440000.+	ΔV	$\Delta(B-V)$	J.D. (Hel) 2440000.+	ΔV	$\Delta(B-V)$
1981–82 Observing Season					
4973.1826	1.447	.385	5015.1411	1.508	.356
4984.2340	1.468	.377	5017.1169	1.497	.368
4985.2009	1.527	.373	5018.1019	1.467	.387
4986.2120	1.527	.381	5018.1405	1.439	.372
4987.2038	1.433	.403	5019.1302	1.440	.368
4990.2144	1.425	.364	5021.1255	1.424	.367
4991.2170	1.500	.382	5022.1279	1.463	.397
4992.2390	1.508	—	5024.1122	1.391	.375
4999.1822	1.463	.359	5025.1368	1.466	.387
5000.1582	1.491	.352	5026.1333	1.467	.394
5002.1701	1.471	.403	5027.1392	1.412	.375
5004.2045	1.441	.354	5028.1323	1.490	.352
5005.0875	1.485	.394	5029.1194	1.497	—
5014.1271	1.513	.380			
1984–85 Observing Season					
6051.2615	1.353	.386	6083.2310	1.377	—
6052.2524	1.457	.355	6087.1817	1.491	.331
6054.2362	1.431	.369	6088.3705	1.393	.341
6055.2800	1.498	.355	6090.1939	1.504	.348
6056.2346	1.540	.352	6094.0984	1.366	.359
1985–86 Observing Season					
6468.0966	1.491	.343	6474.1072	1.489	.345
6468.1126	1.496	.328	6475.1108	1.432	.351
6471.1723	1.473	—	6476.1209	1.498	—
6471.1789	1.450	—	6506.1008	1.427	—
6472.0868	1.455	.332	6506.1122	1.440	—
6472.1080	1.440	.345			
1986–87 Observing Season					
6800.2295	1.506	—	6824.2344	1.452	—
6801.2028	1.495	—	6825.1949	1.470	.331
6801.2361	1.490	.333	6825.2220	1.456	—
6801.2529	1.496	.336	6827.1826	1.444	—
6802.2481	1.471	.322	6828.1271	1.484	—
6803.2501	1.497	.313	6829.1268	1.470	—
6803.2674	1.496	.310	6830.1739	1.442	.323
6804.1770	1.476	.328	6831.2020	1.488	—
6816.1941	1.437	—	6832.1510	1.479	.330
6817.2065	1.500	—	6832.1700	1.478	.322
6818.1829	1.480	—	6833.1203	1.427	—
6819.1811	1.437	.330	6835.0898	1.471	.325
6820.1861	1.488	.337	6836.0927	1.429	.327
6821.1555	1.501	—	6847.1174	1.439	.333

Table 1. continued

1986–87 continued					
6823.2257	1.464	.322	6850.1375	1.437	.324
6851.1340	1.504	.331	6861.1166	1.453	—
6852.1361	1.476	.325	6862.1370	1.494	—
6860.0944	1.473	.326			
1987–88 Observing Season					
7157.0878	1.529	.351	7203.1573	1.530	.339
7176.1877	1.501	.350	7204.1308	1.492	.350
7178.2149	1.486	.337	7205.1220	1.522	.373
7179.2051	1.508	.350	7206.1028	1.518	.350
7183.1171	1.527	.357	7207.0914	1.494	.350
7184.2170	1.481	.360	7208.1213	1.519	.350
7185.1299	1.518	.340	7217.0983	1.523	.353
7196.1695	1.515	.353	7220.0927	1.526	.350
7197.1599	1.538	.343	7230.1128	1.489	.350
7198.0985	1.497	.350	7231.1316	1.533	.332
7200.1361	1.532	.342	7232.1385	1.481	.344
7201.1487	1.497	.339	7233.1345	1.499	.391
7202.1040	1.515	.344			
1988–89 Observing Season					
7530.2771	1.485	—	7560.1645	1.515	.328
7556.1457	1.526	.323	7561.1728	1.466	.340
7557.1590	1.508	.323	7564.1615	1.474	.328
7558.1461	1.485	.332	7572.0993	1.521	.331
7559.1668	1.546	.324	7573.1363	1.519	.333
1989–90 Observing Season					
7852.3223	1.479	.332	7912.2406	1.450	.326
7853.2548	1.428	.322	7913.1199	1.401	.337
7854.2557	1.511	.325	7914.1637	1.521	—
7855.2955	1.465	.331	7915.1755	1.432	.329
7856.2702	1.428	.327	7916.1580	1.437	.324
7867.3277	1.419	.334	7917.1477	1.497	.330
7878.2829	1.442	.315	7918.1506	1.445	.329
1990–91 Observing Season					
8279.1963	1.485	—	8299.1111	1.488	.328
8280.1142	1.531	.319	8300.1172	1.533	.348
8296.2181	1.482	.339	8301.1420	1.531	.347
8297.1464	1.521	.339	8302.1198	1.484	.350
8298.1352	1.559	.332	8303.1152	1.546	.343
8305.1473	1.487	.337	8330.1098	1.506	.305
8306.1394	1.534	.344	8331.0869	1.513	.340
8325.1406	1.517	.297	8332.0892	1.540	.330
8326.1363	1.557	.323	8333.0876	1.498	.336
8327.1236	1.504	.333	8334.0863	1.512	.325
8328.1167	1.519	.328	8335.0937	1.536	.364
8329.1308	1.555	.315			

Table 2. Hα data of V711 Tau

Date	JD 2440000.+	Phase	EW1 Å	FWHM Å	Height	EW2 Å
10 Oct 1990	8175.4521	0.176	0.90	4.51	0.21	−0.22
11 Oct 1990	8176.4944	0.543	0.71	3.04	0.23	−0.74
23 Nov 1990	8219.3264	0.636	1.09	3.47	0.28	+0.17
28 Nov 1990	8224.3451	0.405	0.82	2.96	0.27	−0.27
28 Nov 1990	8224.3854	0.419	0.77	2.99	0.27	−0.50
29 Nov 1990	8225.3333	0.753	1.00	3.24	0.27	−0.19
30 Nov 1990	8226.3486	0.111	1.03	5.36	0.21	+0.03
30 Nov 1990	8226.3833	0.123	1.01	5.37	0.20	−0.03
07 Jan 1991	8264.2167	0.455	1.03	4.36	0.21	−0.08
07 Jan 1991	8264.2715	0.474	0.93	4.29	0.22	−0.31
08 Jan 1991	8265.1917	0.798	0.96	3.35	0.28	+0.07
08 Jan 1991	8265.2840	0.831	0.83	2.91	0.29	−0.46
06 Feb 1991	8294.2153	0.026	0.25	2.88	0.12	−0.99
06 Feb 1991	8294.2389	0.034	0.28	3.14	0.11	−0.77
07 Feb 1991	8295.1882	0.369	1.22	3.98	0.30	+0.24
07 Feb 1991	8295.2118	0.377	1.16	3.96	0.30	+0.14
08 Feb 1991	8296.1847	0.720	0.81	3.80	0.24	−0.21
06 Mar 1991	8322.1361	0.865	0.72	2.68	0.26	−0.88
08 Mar 1991	8324.1306	0.567	0.91	3.18	0.27	−0.85

Table 3. Photometric characteristics of V711 Tau

Epoch	Amplitude	ΔV_{max}	ΔV_{min}	Phase Min	References
1975.85	0.095	1.525	1.620	0.59±0.15	Bopp et al. (1977)
1975.95	0.115	1.490	1.605	0.63±0.05	Bopp et al. (1977)
1976.02	0.135	1.465	1.595	0.63±0.05	Bopp et al. (1977)
1976.13	0.090	1.495	1.585	0.54±0.07	Bopp et al. (1977)
1976.76	0.115	1.495	1.610	0.57±0.07	Landis et al. (1978)
1976.91	0.120	1.500	1.620	0.63±0.05	Landis et al. (1978)
1977.14	0.115	1.495	1.610	0.55±0.11	Parthasarathy et al. (1981)
1977.72	0.110	1.500	1.610	0.60±0.07	Bartolini et al. (1978)
1978.00	0.085	1.505	1.590	0.70±0.10	Bartolini et al. (1978)
1978.18	0.072	1.520	1.592	0.72±0.08	Chambliss et al. (1978)
1978.91	0.190	1.460	1.650	0.89	Bartolini et al (1983)
1979.08	0.200	1.440	1.640	0.90±0.01	Sarma & Ausekar (1980)
1979.11	0.210	1.440	1.650	0.91±0.01	Bartolini et al (1983)
1979.15	0.210	1.415	1.625	0.91±0.06	Chambliss & Detterline (1979)
1979.88	0.140	1.450	1.590	0.95±0.01	Bartolini et al. (1983)
1979.91	0.140	1.460	1.600	0.94±0.01	Bartolini et al. (1983)
1979.94	0.140	1.450	1.590	0.99±0.01	Bartolini et al. (1983)
1979.96	0.120	1.490	1.610	0.96±0.01	Bartolini et al. (1983)
1979.98	0.170	1.430	1.600	0.92±0.07	Mekkaden et al. (1982)
1980.00	0.160	1.470	1.630	0.97±0.01	Sarma & Ausekar (1981)

Table 3. continued

Epoch	Amplitude	ΔV_{max}	ΔV_{min}	Phase Min	References
1980.13	0.120	1.450	1.570	0.93±0.02	Bartolini et al. (1983)
1980.14	0.155	1.440	1.595	0.86±0.07	Mekkaden et al. (1982)
1980.73	0.050	1.500	1.550	0.06 0.53	Bartolini et al. (1983)
1980.82	0.060	1.490	1.550	0.05 0.50	Bartolini et al. (1983)
1980.97	0.075	1.490	1.565	0.05 0.50	Bartolini et al. (1983)
1981.04	0.040	1.520	1.560	0.10 0.48	Bartolini et al. (1983)
1981.05	0.053	1.542	1.595	0.02±0.08 0.53±0.07	Mekkaden et al. (1982)
1981.15	0.085	1.530	1.615	0.12±0.08 0.43±0.05	Mekkaden et al. (1982)
1981.19	0.090	1.490	1.580	0.42	Bartolini et al. (1983)
1981.73	0.104	1.510	1.614	0.35±0.05	Rodono et al. (1986)
1981.78	0.100	1.500	1.600	0.30±0.05	Rodono et al. (1986)
1981.91	0.086	1.504	1.590	0.25±0.10	Rodono et al. (1986)
1982.08	0.136	1.391	1.527	0.38±0.04	Mohin et al. (1982)
1983.04	0.055	1.485	1.540	0.33±0.01	Andrews et al. (1988)
1984.00[1]	0.136	1.373	1.509	0.36	Strassmeier et al. (1989)
1985.00[1]	0.167	1.364	1.531	0.33	Strassmeier et al. (1989)
1985.92	0.090	1.450	1.540	0.45	Cutispoto (1990)
1986.00[1]	0.100[2]	1.470	1.570	0.45	Strassmeier et al. (1989)
1986.15	0.070	1.440	1.500	0.45	Present Study
1986.80	0.100	1.440	1.540	0.50±0.01 0.80±0.10	Mekkaden (1987)
1987.17	0.079	1.427	1.506	0.50±0.06 0.89±0.06	Present Study
1988.09	0.052	1.481	1.533	0.43±0.02	Present Study
1989.11	—	—	—	0.47±0.05 0.03±0.05	Present Study
1989.98	0.120	1.401	1.521	0.07±0.01	Present Study
1991.16	0.075	1.484	1.559	0.33±0.01	Present Study

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[1] Mean epoch as quoted by Strassmeier et al. (1989).

[2] Amplitude is evaluated from the graph.

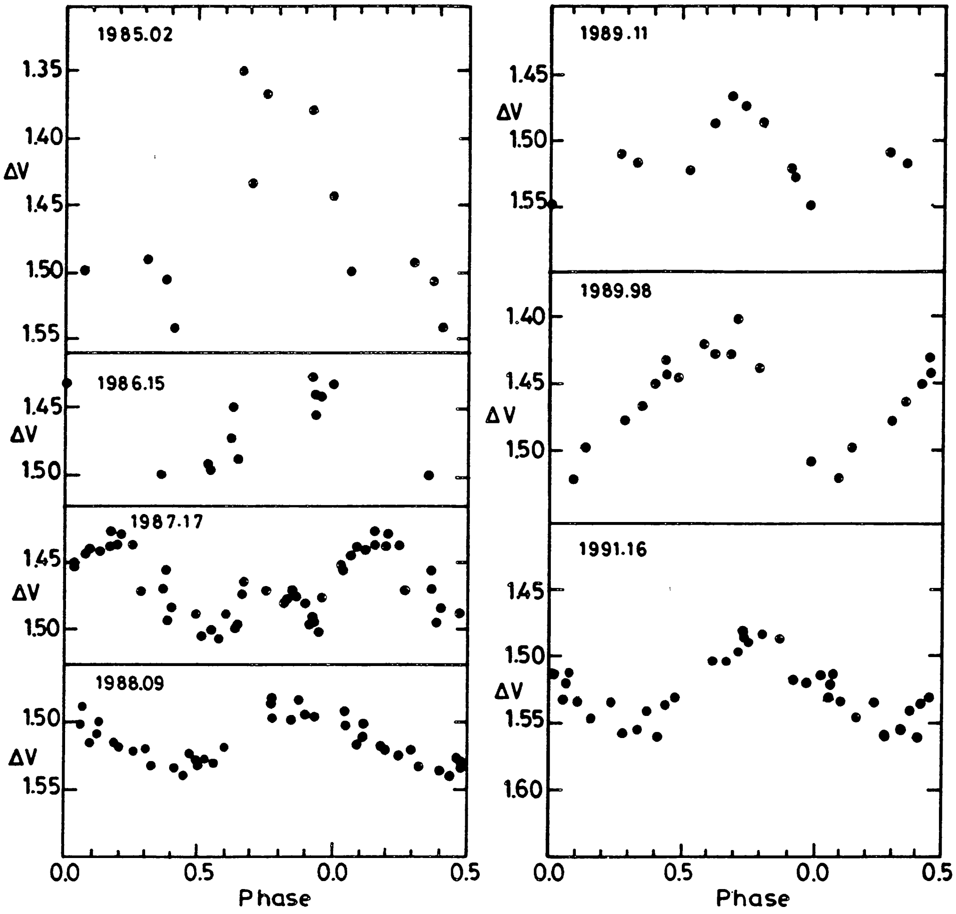

Fig. 1. The V light curves of V711 Tau obtained during the years 1984-91. Phases are reckoned from JD (Hel.) 2442766.069 using the period $2^{d}.83782$

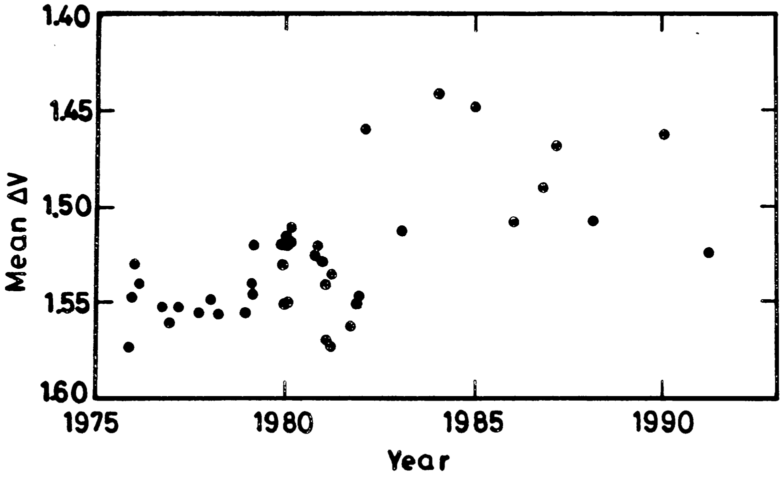

Fig. 2. Plot of mean ΔV against the corresponding mean epoch of observation

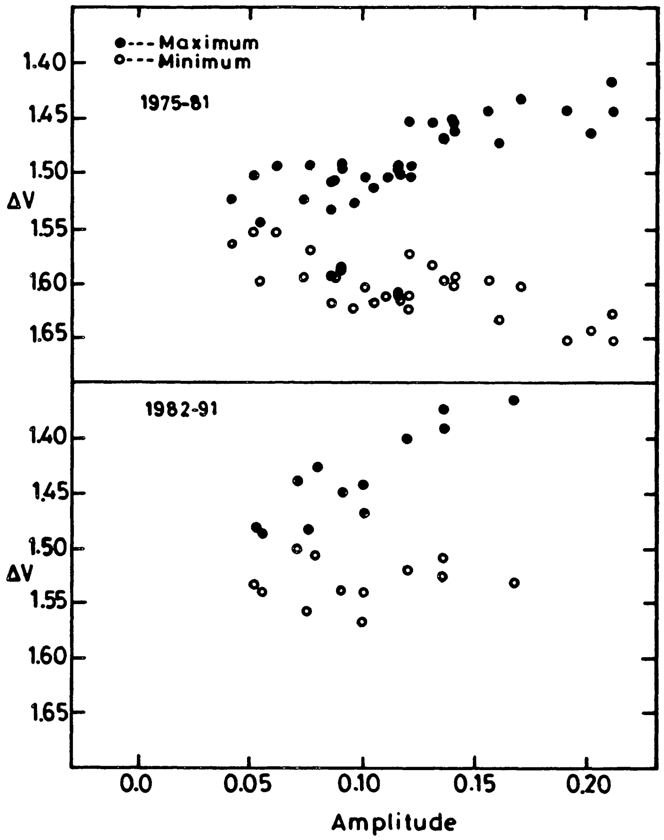

Fig. 3. Plot of the brightness at light maximum (filled circles) and light minimum (open circles) against the V amplitude during the periods 1975-81 (top panel) and 1982-91 (bottom panel)

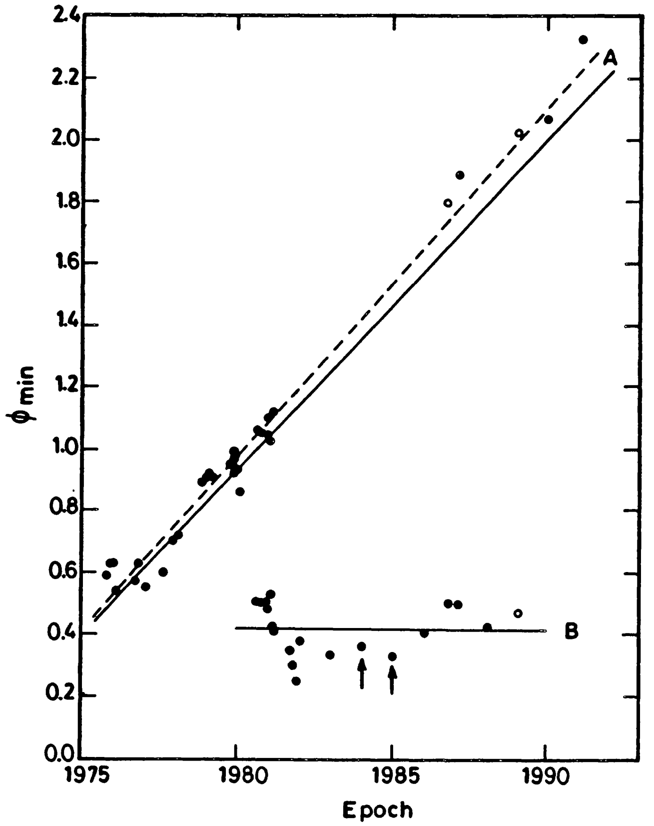

Fig. 4. Plot of the phase of light minimum versus mean epoch of observation

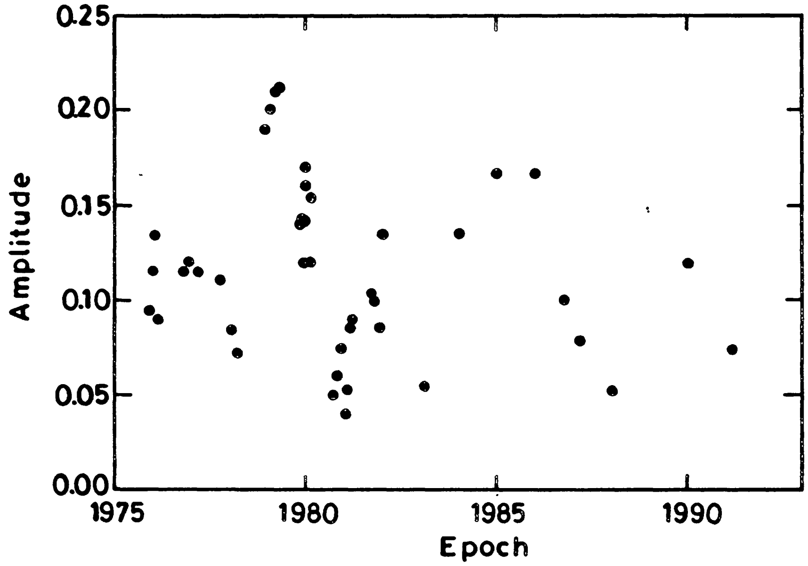

Fig. 5. Plot of V amplitude against the mean epoch of observation

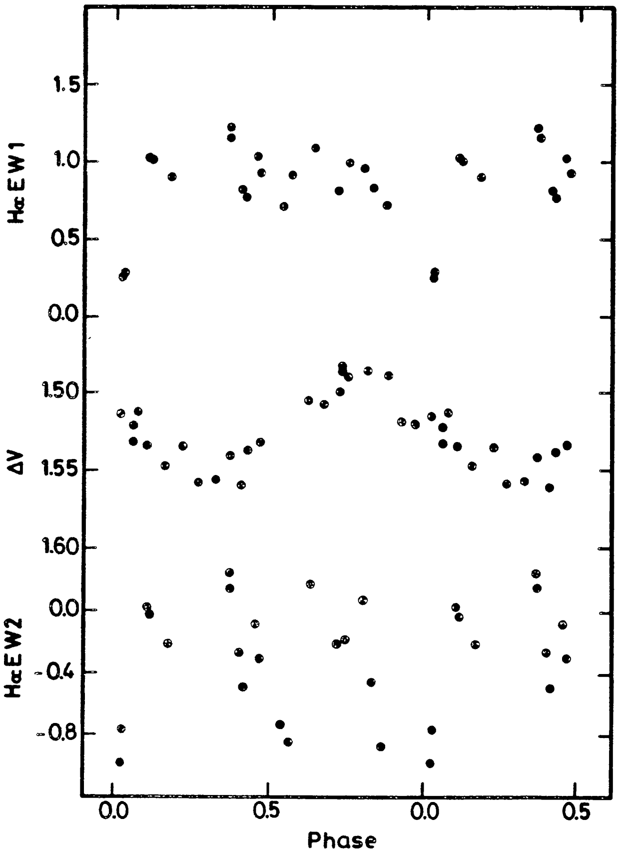

Fig. 6. Top panel shows the variation of EW1, middle panel the V light curve and the bottom panel the variation of EW2. Phases are reckoned as in Fig. 1