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DISC SYSTEM DELTA CAPRICORNI

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Abstract. First *UBV* photoelectric photometry of the eclipsing binary system δ Cap has been presented. An improved period of $1^d.022766$ has been given. The duration of primary eclipse comes out to be more than double the duration given earlier. The depth has also been found to have increased. The light changes during eclipses show slight asymmetry. Eccentricity appears to be present in the system. Light and colour curves show variations. Primary component appears to be surrounded by a disc, the size of which is comparable to the size of the primary component. Two dips are seen around phases 0.20 and 0.67, the first appears more definitive, and is attributed to the wave-like distortion, like the one found in RS CVn binaries. The discussion reveals that δ Cap is a very complicated system.

1. Introduction

Variable radial velocity in δ Cap (BD − 16° 5943 = HD 207098) was first detected by Slipher (1906). It was known to be a single line spectroscopic binary. Spectroscopic studies of δ Cap were presented by Crump (1921), Luyten (1936), Stewart (1958), and Batten (1961). The radial velocity amplitude was found to be variable. Kitamura and Okazaki (1977) found variable metallism in the primary component of δ Cap. Srivastava (1987) described it to be a RS CVn binary system.

Eggen (1956), Wood and Lampert (1963), Dorren *et al.* (1980), and Ohmori (1981) secured photometric observations of δ Cap, but none of these photometries were satisfactory on the following counts:

(1) Eggen (1956) secured two nights of *V* observations wherein only primary minima was covered. He could not decide the nature of the eclipse observed by him.

(2) Wood and Lampert (1963) obtained six nights of *B* and *V* observations, wherein they could not cover the mid-eclipse portion of the primary eclipse, thus they could not definitely ascertain the depths of minima in two colours.

(3) Dorren *et al.* (1980) secured thirthy-nine nights of Hα observations wherein considerably large scatter was present. They thought it to be intrinsic to δ Cap, but could not classify the variability of this scatter.

(4) Ohmori (1981) obtained thirteen nights of *B* and *V* observations, wherein the secondary minimum was not covered.

It is evident from the above that none of these photometries are up to the mark. Moreover, none had attempted its photometry in all the three (*U*, *B*, and *V*) colours. Also the photoelectric secondary minima are hardly available in the literature. This situation led us to attempt a fresh photometry of δ Cap in *U*, *B*, and *V* colours.

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2. Observations

The eclipsing binary system δ Cap was observed photoelectrically on the 38-cm reflector of the Uttar Pradesh State Observatory, using a cooled (-20 °C) 1P21 photomultiplier tube and *U*, *B*, and *V* filters of Johnson and Morgan systems, and d.c. amplifier.

A total of seven nights of observations were secured during the period September 1979 to October 1982. The stars γ Cap and ε Cap were used as the comparison and check stars, respectively. The data were reduced to the standard system from the observations of four standard stars. The particulars of the variable and the comparison stars alongwith the standard deviations are given in Table I, wherein the given spectral-types are the present ones.

TABLE I
Particulars of the variable and the comparison star

Star	α_{1981}	δ_{1981}	Sp. (present)	Average standard deviation of the individual observations in *U*, *B*, and *V* filters
δ Capricorni (= BD − 16°5943)	$21^h48^m27\overset{s}{.}8$	$-16°00'28\overset{''}{.}0$	F0IV	–
Comparison γ Capricorni	21 45 31.0	− 11 27 23.7	F3II	$\pm 0\overset{m}{.}039$ (*U*) $\pm 0\overset{m}{.}032$ (*B*) $\pm 0\overset{m}{.}021$ (*V*)

In all 74 (*U*), 78 (*B*), and 77 (*V*) observations have been obtained. The standard differential magnitudes (ΔU, ΔB, and ΔV), in the sense 'variable *minus* comparison' and standard differential colour indices have been listed in Tables VI, VII, VIII, and IX, respectively, and are plotted in Figure 1.

3. Epoch and Period

During the course of our observations one primary and one secondary minima have been observed. These times of minima have been determined using the graphical method with an accuracy of $0\overset{d}{.}001$, and are listed in Table II along with the O–C values.

Using the epoch given in GCVS (1969), Primary Min. = J.D. 2435656.911 + $1\overset{d}{.}022768E$, the period on the basis of our minima comes out to be $1\overset{d}{.}022766$ ($\pm$ $0\overset{d}{.}000003$). Not much is commented on the period of δ Cap in the literature, however, the period does not appear to be strictly constant.

Wood and Lampert (1963) indicated from their short time-interval study that there was no guarantee that the period was constant between the time interval from Eggen's

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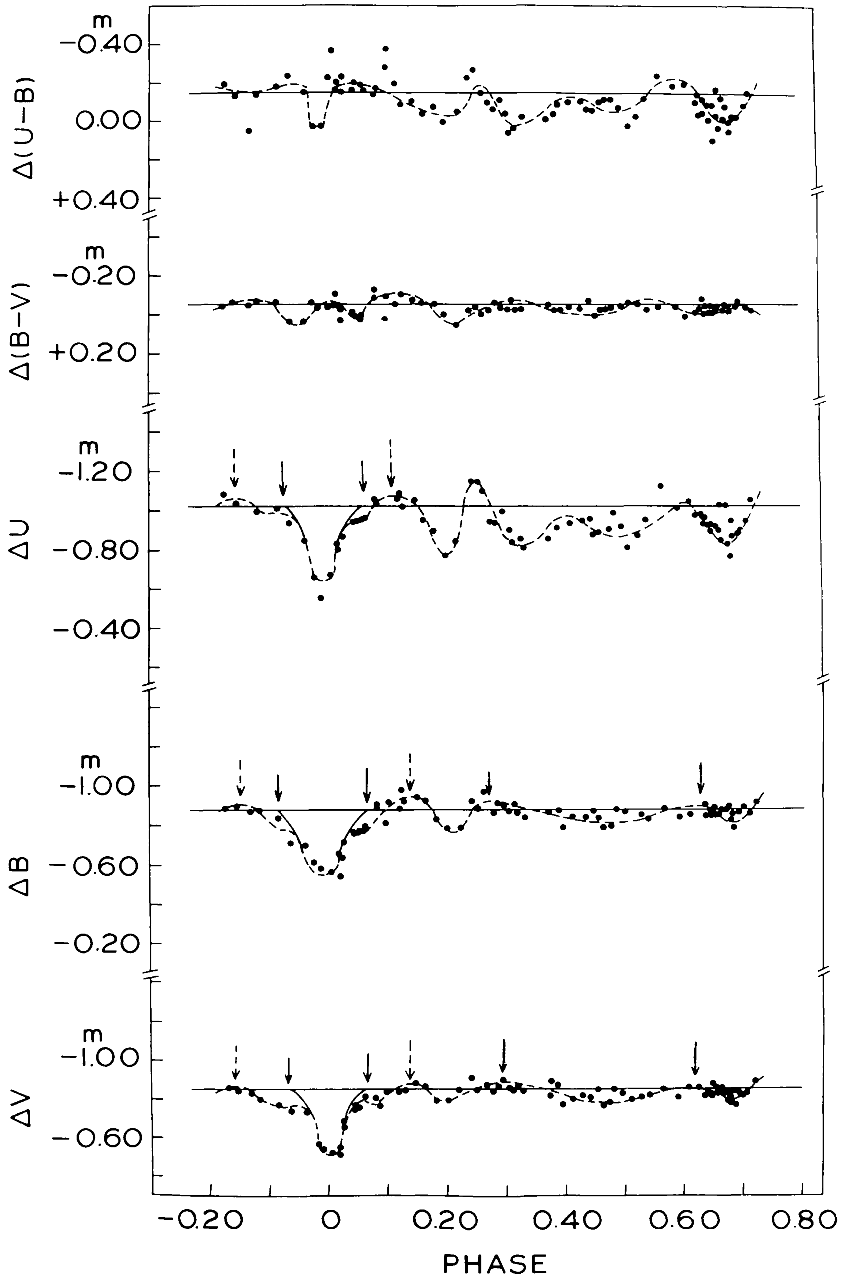

Fig. 1. Light and colour curves of δ Cap. Solid arrows indicate the start and end of the eclipse of components, while the discontinuous arrows show the start and end of the eclipse of disc.

(1956) to their observations. However, Dorren *et al.* (1980) did not find any significant change in the period of δ Cap. They stated that the secondary minimum appeared to have occurred close to 0.50 phase. This fact is in contradiction to our findings that the secondary minimum is considerably shifted from its position, which fact deserves attention.

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TABLE II

Observed minima of δ Cap

Minima, J.D. (Hel.)	Cycle	O–C based on the epoch and period given in GVCS (1969)
Primary		
2444163.272	8317	$-0^d.001$
Secondary		
2445261.168	9390	$-0^d.046$
	Mean	$-0^d.024$

4. Analysis of the Light Curves

The *U*, *B*, and *V* light curves (Figure 1) have been fairly covered except the portion between phases 0.72 to 0.83, which is no limitation in discussion of the light curve features.

The observed depths of minima, obtained by various authors, are given in Table III. Comparing the depths of minima in *V* filter, it is apparent that the depths of minima are changing. The depths of primary minimum change more than the depths of secondary minimum. Present depth of primary minimum comes out to be nearly double

TABLE III

Depths of minima of δ Cap

Sl. No.	Author	Filter	Primary minimum	Secondary minimum
1	Eggen (1956)	*V*	$0^m.16$	–
2	Abt (1961)	–	$0^m.10$	–
3	GCVS (1969)	*V*	$0^m.17$	–
4	Wood and Lampert (1963)	*B*, *V*	Few hundredths of a magnitude greater than that found by Eggen (1961), i.e., $>0^m.16$	–
5	Dorren *et al.* (1980)	Hα	$0^m.18$	$0^m.05$
6	Ohmori (1981)	*B*	$0^m.217$	$0^m.114$
		V	$0^m.147$	$0^m.090$
		Mean	$0^m.182$	$0^m.102$
7	GCVS (1985)	*V*	$0^m.24$	–
8	Srivastava (present)	*U*	$0^m.380$	$0^m.150$
		B	$0^m.330$	$0^m.090$
		V	$0^m.320$	$0^m.070$
		Mean	$0^m.340$	$0^m.103$

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in *B* and *V* filters. On the other hand, the depth of secondary minimum also shows insignificant change within error of observations.

5. Eccentricity

The duration of primary eclipses are $0^{d}.271$ (*U*), $0^{d}.266$ (*B*), and $0^{d}.297$ (*V*), while the duration of secondary eclipses are $0^{d}.362$ (*U*), $0^{d}.368$ (*B*), and $0^{d}.330$ (*V*). The averages of primary and secondary eclipses being $0^{d}.282$ and $0^{d}.353$, respectively. Thus, primary and secondary eclipses have unequal durations. It is also apparent that the secondary eclipse has largest duration in *V*, while the primary minimum has the lesser duration in *V*. Also, the present average duration of primary eclipse ($6^{h}38^{m}$) comes out to be more than double the duration of the primary minimum quoted earlier (cf. Wood *et al.*, 1980) – i.e., 3^{h}.

It is apparent from Table II that primary and secondary minimary are shifted earlier by $0^{d}.001$ and $0^{d}.046$, respectively. The shift of primary minimum is within the error of determination of minimum, thus, the secondary minimum reveals a considerable shift from its positron. Evidently, the two minima are unequally shifted.

Crump (1921) found that the eccentricity is zero, while Stewart (1958) had found the eccentricity significantly greater than zero. Other spectrographic observations along with these reveal that $e = 0.01$ to 0.03. Since we have stated above that the system δ Cap has unequal shifts and unequal durations of minima along with small asymmetry. Thus, the presence of eccentricity is a definite possibility in δ Cap, which fact is contrary to the findings of Crump (1921). Quantitative determination of eccentricity is not feasible at the moment, as sufficient times of minima in a short interval of time are desired.

6. Gaseous Stream and Disc

Considering the average level of maximum in *U*, *B*, and *V* filters, the dips of $0^{m}.1$ are visible on both the branches of primary minimum. The dips are centered around $\pm 0^{p}.07$. The maxima faling preceding the start of descending branches of primary minimum is lower than the maxima following the end of ascending branch of primary minimum, by $0^{m}.02$ on the average. Thus, slight asymmetry at the first and fourth contact of the eclipse is visible. Also, the maxima falling around $0^{p}.20$ and $0^{p}.62$ differ in height by nearly $0^{m}.04$ (*U*), $0^{m}.05$ (*B*), and $0^{m}.01$ (*V*), the average being $0^{m}.03$. These facts suggest the presence of gas streaming in δ Cap. The stream of gas may emanate from the fainter component (assuming the primary eclipse to be a total occultation) and impinge on the trailing hemisphere of the primary component, thereby creating a hot spot. The light curve of U Cephei provides a similar clue to the course of stream in the system (cf. Batten, 1973), wherein between $0^{p}.8$ and $0^{p}.9$ the total light of the system decreases by about $0^{m}.1$, and shoulder of the preceding eclipse is lower than the following by this amount. Such effect can be caused by the presence of gaseous matter forming a shell or disc around the primary component of δ Cap. Similar effect has also been observed

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in β Per (Guinan *et al.*, 1976), RW Per (Hall and Stuhlinger, 1979), RT Per (Sanwal and Chaubey, 1979), and DI Peg (Chaubey, 1982).

The duration of eclipse has changed from 3^h (cf. Wood *et al.*, 1980) to $6\overset{h}{.}65$ (present). It is more likely that the change of primary eclipse was caused not by an actual expansion of the hotter star but by the development of a shell or disc. The possibility of a shell has been negated on two grounds: First, the shell stars usually belong to spectral type B; secondly, the rotational velocity of the primary component has been found to be < 90 km s^{-1}, which is below the limit of fast rotators or shell stars. In addition, Hα emission has not been described in any earlier spectroscopic studies. Also, Slipher (1906) described δ Cap primary as a metallic line star and stated that it does not show obvious similarity to recognised 'shell-spectrum'. Now only two possibilities remain to be explored, the presence of an extended atmosphere and that of the disc. Since the amount of light loss (in the depression) are such as to imply that the phenomenon is independent of wavelength. Secondly, the beginning of the primary eclipse is not considerably differed in the three wavelengths; hence, the possibility of the extended atmosphere is negated. Thus, it is evident that the hotter component is surrounded by a disc of circumstellar material, which is luminous by scattered light in the plane of the orbit. The reduction of the light on the two branches of eclipse is due to the eclipse of the disc by the fainter component (before and after the primary component is eclipsed). Actual durations of the eclipse of the primary component come out to be $0\overset{d}{.}135$ (U), $0\overset{d}{.}152$ (B), and $0\overset{d}{.}138$ (V), the average being $0\overset{d}{.}142$, which is half the duration of total eclipse. Eggen (1956) estimated the radius of the primary component as $2\,R_\odot$, thus the dimension of the disc is also $2\,R_\odot$ (the duration of the eclipse being the double).

The U, B, V depressions on the two branches of the primary eclipse are not exactly symmetrical in shape; hence, it is possible that the leading and trailing parts of the disc may not be having uniform distribution of the gaseous matter forming the disc or else the disc is not symmetrically placed in the equatorial plane of primary component.

Lastly, our contention of the presence of gaseous stream is further strengthened by the finding of Dorren *et al.* (1980). They found anomalous behaviour of the Hα line strength in δ Cap and attributed it to the presence of gas stream or a hot (or cool) spot on the surface of the hotter component.

7. Colours and Spectral–Luminosity Classification

The photometric colour indices and spectral types of both the components of δ Cap are not available in the literature. The colour indices of the comparison star (γ Cap) have been determined on three nights, and they come out to be $B - V = +0\overset{m}{.}325$ and $U - B = +1\overset{m}{.}443$. The colour indices of the γ Cap have been given in the *Arizona Tonantzintla Catalogue* as $B - V = +0\overset{m}{.}32$, $U - V = +0\overset{m}{.}21$, F0II$_p$). Comparing our observed values with the given ones, it is apparent that $B - V$ value obtained by us is in agreement with the catalogued value, while the $U - B$ vlaue is totally different. Thus, for the purpose of determination of colour indices, we adopt the comparable $U - B$ value, i.e., $0\overset{m}{.}21$. These values ($B - V = +0\overset{m}{.}325$, $U - B = +0\overset{m}{.}210$) place the com-

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parison star in F3II-type, with an ultraviolet excess of $1^m.233$, obtained on comparing with the standard colour sequences given by Golay (1974). With these values of colour indices we have calculated the values of the colour indices at various phases of δ Cap, and are listed in Table IV. The differential colour indices $\Delta(B - V)$ and $\Delta(U - B)$ have been listed in Table IX, and are plotted on the top of Figure 1.

Now to what extent we are justified in adopting the $U - B$ values given in the catalogue? On the basis of observed $B - V$ colour index and on the basis of adopted $U - B$ colour index, we have derived the colour indices of the system, and of primary and secondary components (Table IV). These indicate that their spectral types are F0IV, A9III, and F1III, respectively. The spectral type of the primary component has been variously quoted as A7III, thus, our present spectral luminosity classification is in near agreement to those given in the literature and, hence, it is evident that we are fully justified in adopting the catalogued $U - B$ value for the comparison star. Unfortunately, nobody could determine the spectral type of the secondary component in the literature. Dorren *et al.* (1980) have assessed the temperature of the cooler component to be ~ 4700 K, which suggests that the secondary component belongs to G4.5III or K2V–IV spectral luminosity type (cf. Arp, 1958).

TABLE IV

Colours of δ Cap

Phase	$B - V$	$U - B$	Spectral type	UV-excess
System (at maximum)	$+0^m.295$	$+0^m.070$	F0IV	$0^m.01$
Primary component	+0.255	+0.200	A9III	0.09
Secondary component (at the tip of primary minimum)	+0.305	+0.120	F1III	0.03
			Mean	0.04
Comparison	0.325	+0.210 (adopted)	F3II	1.23

Lastly, to what extent our present spectral luminosity types of the individual components are consistent? If we consider the present spectral type of the system (F0IV), primary (A9III), and secondary component (G4.5III or K2V–IV), it is evident that the spectral types do not appear consistent. The system has been classified as A5V to F5IV depending on various classification criteria, the mean being F0V–IV. In this light the present spectral type of system is correct. Also mostly, the system's spectral type has been quoted as A5. If we consider Dorren *et al.*'s (1980) spectral type of the secondary component as G4.5III or K2V–IV, then the spectral type of the primary component should lie around O-type, which is not the case as they assessed the spectral type of the primary component as A7m. If we consider the above discussion, it is apparent that our

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present spectral types are fully consistent, as the spectral type of the system falls exactly in between the spectral types of the individual components.

Now, there appears one inconsistency: when we consider the observed depths of primary and secondary minima as $0^m.34$ and $0^m.10$, respectively, these suggest that the secondary component is 3.4 times fainter than the primary (assuming the primary eclipse to be total occultation), but the present obtained spectral types do not allow us to have this ratio of depths. In addition, Batten (1961) had stated that the secondary component must be three magnitudes fainter than the primary. Table III indicates that the depths of minima change, the depth of primary strongly, hence, we feel some other explanation such as spot or flare activity, third body impact on the total light of the system, should be invoked, but the possibility of a third light has not been established so far (Srivastava, 1987). Thus, the only explanation of activity is left out for future, which appears reasonable to search out in the light of declaration by Srivastava (1987) that δ Cap is a RS CVn binary system.

In this context, it is also possible that the observed depths of the primary and the secondary minima are not correct. The observed depths of secondary minima, $0^m.07$ (V), is fairly in the line of depths observed by Dorren *et al.* (1980), $0^m.05$ (Hα), and Ohmori (1981), $0^m.09$ (V), within scatter of observations. Likewise the depth of primary minimum, $0^m.32$ (V) is also in line of the depths given by Eggen (1956), $0^m.18$ (Hα), and Ohmori (1981), $0^m.15$ (V), GCVS (1969), $0^m.17$ (V), and GCVS (1985), $0^m.24$ (V) (in view that the depth of the primary component is variable by about $0^m.1$). Thus, it appears that the present depths of both minima are consistent with the depths of minima given earlier as such they are correct. It is now clear that no single model can explain the complicated behaviour of δ Cap.

8. Intrinsic Variability Negated

Both light and colour curves show variations throughout the cycle. Light and colour curves show variations ranging from $0^m.06$ to $0^m.29$ and $0^m.08$ to $0^m.21$, respectively. These can be caused by the intrinsic variability of either or both the components of δ Cap. Since larger scatter is visible at the tip of the secondary eclipse, hence, it is apparent that the primary component is responsible for the large scatter. It is also more probable as the depth of the secondary does not vary appreciably compared to the depth of primary. If we consider that these variations are due to intrinsic variability, then looking at the present amplitudes, durations of these variations and the spectral types of the components, it is difficult to assign them any type of classified intrinsic variability. In addition, the phases of maxima and minima both in different filters and colours, do not show similar behaviour. Thus, for the time being it is difficult to ascertain the presence of intrinsic variability.

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9. Cool Spots and Activity Signatures

We are unable to explain the light and colour curve variations on the basis of intrinsic variability of the components. Thus, we will look into some other mechanism like presence of cool spots and stellar activity to explain these variations.

Srivastava (1987) had already declared δ Cap to be a RS CVn binary from his photoelectric observations. Srivastava (1987) had also stated that sudden period changes were present in δ Cap. These facts are important.

Two dips of $0\overset{m}{.}18$ and $0\overset{m}{.}11$ at $0\overset{p}{.}20$ and $0\overset{p}{.}67$ are visible in the light curves. The second is found to lie at $0\overset{p}{.}64$ in $B - V$ and at $0\overset{p}{.}68$ in $U - B$ having amplitudes of $0\overset{m}{.}08$ and $0\overset{m}{.}21$, respectively. Can these be due to the presence of cool spots or owing to distortion wave minimum generated by the movements of cool spots? The position of dips alongwith their amplitudes in different filters and colours are given in Table V.

TABLE V

Dips of δ Cap

Filter	Dip I		Dip II		Colour	Dip I		Dip II	
	Phase	Amplitude	Phase	Amplitude		Phase	Amplitude	Phase	Amplitude
U	0.200	$0\overset{m}{.}290$	0.672	$0\overset{m}{.}200$	$B - V$	0.217	$0\overset{m}{.}150$	0.640	$0\overset{m}{.}080$
B	0.210	0.170	0.672	0.070	$U - B$	0.210	0.180	0.680	0.210
V	0.190	0.080	0.675	0.060					
Mean	0.200	0.180	0.673	0.110		0.214	0.165	0.660	0.145

We consider that these dips are due to the cool spots, which are situated on either component, and these dips are the outcome of migrating distortion wave minimum. If the distortion wave minima lie at $0\overset{p}{.}20$ and $0\overset{p}{.}67$ then, for a symmetrical wave, the respective maxima must lie at $0\overset{p}{.}70$ and $0\overset{p}{.}17$. Firstly, the U, B, and V light curves fairly show an upward tendency around $0\overset{p}{.}70$ (the observations between phases 0.72 and 0.82 are absent), however, such indication is not apparent at maxima around $0\overset{p}{.}17$. Thus, the dip around $0\overset{p}{.}20$ appears more definitive being caused by the distortion wave minimum. Secondly, the position of dip around $0\overset{p}{.}20$ differ by only $0\overset{p}{.}01$ in different filters and colour curves, while the position of the dips around $0\overset{p}{.}67$ differs by as much as $0\overset{p}{.}04$ in different filters and colours, thus also, the dip around phase $0\overset{p}{.}20$ is a more significant signature of existence of spots compared to the dip around $0\overset{p}{.}67$.

What is the evidence of stellar activity? The large scatter present in our U and B observations is the first sign of stellar activity because the possibility of intrinsic variability has already been negated, and also, because the comparison γ Cap is found to behave constantly against the check star ε Cap.

The supportive evidence is first found in the observations of Crump (1921) and Dorren *et al.* (1980), which possessed considerably large scatter. Secondly, Wood and

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Lampert (1963) stated that they found changing light levels in δ Cap. Third, Dorren *et al.* (1980) found variable α-index in their Hα observations, which is a measure of net strength of the Hα line. Unfortunately, last spectroscopic observations were published in 1961, hence, the present spectral behaviour of δ Cap, if changed at all, is not known. Since δ Cap has shown new features of a disc, changed duration of primary eclipse and largest depth of primary minimum in the present observations; hence, it is possible that its spectral behaviour must have also changed. Although it is difficult to confirm the presence of cool spots in δ Cap on the basis of presently available literature, its possibility

TABLE VI

Standard *U* observations of δ Cap

J.D. (Hel.)	Phase	ΔU	J.D. (Hel.)	Phase	ΔU
2444163.0959	0.8275	$-1^m.078$	2444895.2384	0.6715	$-1^m.020$
.1154	0.8464	−1.025	.2461	0.6791	−0.937
.1375	0.8680	−0.820	.2520	0.6848	−0.870
.1530	0.8832	−0.994	908.0920	0.2390	−1.135
.1867	0.9162	−1.008	.1028	0.2496	−1.138
.2067	0.9357	−0.926	.1148	0.2613	−1.101
.2359	0.9613	−0.835	.1290	0.2752	−0.938
.2481	0.9762	−0.645	.1376	0.2836	−0.942
.2608	0.9886	−0.538	.1468	0.2926	−0.989
.2777	0.0051	−0.668	.1584	0.3039	−0.888
.2927	0.0198	−0.797	.1633	0.3087	−0.820
517.1679	0.0173	−0.832	.1714	0.3166	−0.801
.1757	0.0249	−0.846	.1801	0.3251	−0.833
.1791	0.0283	−0.859	935.0850	0.6311	−0.926
.1997	0.0484	−0.925	.0933	0.6392	−0.916
.2007	0.0494	−0.941	.1018	0.6475	−0.927
.2124	0.0608	−0.947	.1086	0.6542	−0.920
.2159	0.0643	−0.945	.1144	0.6598	−0.900
.2362	0.0841	−1.026	.1206	0.6659	−0.835
.2368	0.0847	−1.053	.1275	0.6727	−0.816
.2739	0.1210	−1.058	.1368	0.6817	−0.757
.2753	0.1223	−1.079	.1462	0.6909	−0.875
554.1021	0.1293	−1.014	.1532	0.6978	−0.897
.1208	0.1476	−1.029	.1622	0.7066	−0.940
.1380	0.1644	−0.954	.1710	0.7152	−1.046
.1553	0.1813	−0.892	2445261.0898	0.3713	−0.854
.1748	0.2004	−0.768	.1053	0.3865	−0.898
.1935	0.2187	−0.844	.1287	0.4093	−0.928
895.1022	0.5384	−0.950	.1424	0.4301	−0.925
.1273	0.5629	−1.125	.1553	0.4427	−0.936
.1543	0.5893	−1.014	.1646	0.4518	−0.881
.1730	0.6076	−1.040	.1746	0.4616	−0.877
.1909	0.6251	−0.978	.1855	0.4722	−0.908
.1977	0.6317	−0.984	.1980	0.4845	−0.989
.2049	0.6388	−0.964	.2097	0.4959	−0.921
.2132	0.6469	−0.899	.2221	0.5080	−0.804
.2303	0.6636	−1.025	.2399	0.5254	−0.875

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cannot altogether be ruled out, as it has revealed considerable similarity to the RS CVn binaries (Srivastava, 1987).

10. Conclusions

The first photoelectric photometry of eclipsing binary system δ Cap in all the three (U, B, and V) filters has been presented. Although, the system is very bright, yet it has

TABLE VII

Standard B magnitudes of δ Cap

J.D. (Hel.)	Phase	ΔB	J.D. (Hel.)	Phase	ΔB
2444163.0965	0.8280	$-0^m.884$	2444895.2307	0.6640	$-0^m.867$
.1160	0.8470	−0.892	.2389	0.6720	−0.897
.1383	0.8688	−0.870	.2467	0.6796	−0.856
.1535	0.8837	−0.866	.2525	0.6853	−0.876
.1872	0.9166	−0.834	908.0925	0.2395	−0.913
.2071	0.9361	−0.697	.1033	0.2500	−0.877
.2334	0.9618	−0.694	.1151	0.2616	−0.964
.2485	0.9766	−0.605	.1299	0.2761	−0.849
.2614	0.9892	−0.572	.1382	0.2842	−0.895
.2783	0.0057	−0.555	.1473	0.2931	−0.892
.2934	0.0205	−0.538	.1588	0.3043	−0.865
517.1706	0.0200	−0.646	.1639	0.3093	−0.891
.1763	0.0255	−0.625	.1723	0.3175	−0.853
.1785	0.0277	−0.705	.1806	0.3256	−0.834
.1988	0.0475	−0.763	935.0856	0.6317	−0.898
.2013	0.0500	−0.757	.0937	0.6396	−0.873
.2130	0.0614	−0.765	.1023	0.6480	−0.851
.2153	0.0637	−0.794	.1091	0.6547	−0.851
.2355	0.0834	−0.897	.1149	0.6603	−0.877
.2376	0.0855	−0.892	.1211	0.6664	−0.878
.2541	0.1016	−0.814	.1284	0.6735	−0.808
.2560	0.1035	−0.909	.1384	0.6833	−0.770
.2733	0.1204	−0.884	.1467	0.6914	−0.870
.2760	0.1230	−0.979	.1537	0.6983	−0.891
554.1026	0.1298	−0.933	.1630	0.7074	−0.858
.1212	0.1480	−0.940	.1716	0.7158	−0.908
.1383	0.1647	−0.922	2445261.0902	0.3717	−0.857
.1560	0.1820	−0.839	.1059	0.3871	−0.871
.1754	0.2010	−0.782	.1144	0.3954	−0.780
.1939	0.2191	−0.777	.1298	0.4104	−0.835
895.1027	0.5389	−0.839	.1430	0.4307	−0.839
.1282	0.5638	−0.888	.1557	0.4431	−0.884
.1547	0.5897	−0.836	.1651	0.4523	−0.842
.1733	0.6079	−0.851	.1751	0.4621	−0.786
.1913	0.6255	−0.875	.1860	0.4727	−0.797
.1980	0.6320	−0.853	.1985	0.4849	−0.886
.2053	0.6392	−0.853	.2101	0.4963	−0.866
.2136	0.6473	−0.891	.2227	0.5086	−0.846
.2226	0.6561	−0.860	.2404	0.5259	−0.852

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TABLE VIII

Standard V observations of δ Cap

J.D. (Hel.)	Phase	ΔV	J.D. (Hel.)	Phase	ΔV
2444163.0970	0.8284	$-0^m.845$	2444895.2394	0.6725	$-0^m.843$
.1164	0.8474	−0.838	.2471	0.6800	−0.822
.1388	0.8693	−0.831	.2529	0.6857	−0.843
.1540	0.8842	−0.802	908.0929	0.2399	−0.901
.1877	0.9171	−0.771	.1037	0.2504	−0.849
.2074	0.9364	−0.738	.1158	0.2623	−0.869
.2339	0.9623	−0.731	.1304	0.2765	−0.832
.2491	0.9772	−0.557	.1386	0.2846	−0.848
.2618	0.9896	−0.533	.1482	0.2939	−0.885
.2787	0.0061	−0.518	.1598	0.3053	−0.853
.2940	0.0211	−0.503	.1650	0.3104	−0.836
517.1699	0.0193	−0.547	.1730	0.3182	−0.846
.1771	0.0263	−0.656	.1815	0.3265	−0.827
.1777	0.0269	−0.675	935.0860	0.6321	−0.832
.1980	0.0468	−0.754	.0941	0.6400	−0.833
.2020	0.0507	−0.764	.1028	0.6485	−0.817
.2138	0.0622	−0.794	.1095	0.6551	−0.849
.2145	0.0629	−0.806	.1155	0.6609	−0.842
.2349	0.0828	−0.813	.1216	0.6669	−0.842
.2383	0.0862	−0.760	.1288	0.6739	−0.786
.2533	0.1008	−0.840	.1389	0.6838	−0.770
.2568	0.1042	−0.822	.1473	0.6920	−0.836
.2726	0.1197	−0.839	.1543	0.6989	−0.831
554.1031	0.1303	−0.841	.1633	0.7077	−0.829
.1219	0.1487	−0.865	.1720	0.7162	−0.894
.1387	0.1651	−0.861	2445261.0906	0.3721	−0.815
.1564	0.1824	−0.790	.1062	0.3873	−0.866
.1758	0.2014	−0.788	.1148	0.3958	−0.766
.1946	0.2198	−0.838	.1305	0.4111	−0.801
895.1030	0.5391	−0.821	.1437	0.4314	−0.805
.1288	0.5644	−0.853	.1562	0.4436	−0.810
.1552	0.5902	−0.806	.1656	0.4528	−0.848
.1745	0.6091	−0.862	.1755	0.4625	−0.767
.1917	0.6259	−0.864	.1866	0.4733	−0.781
.1984	0.6324	−0.822	.1991	0.4855	−0.853
.2059	0.6398	−0.839	.2109	0.4971	−0.831
.2140	0.6477	−0.884	.2234	0.5093	−0.799
.2231	0.6566	−0.840	.2411	0.5266	−0.805
.2313	0.6646	−0.836			

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TABLE IX

Standard colour indices of δ Cap

Phase	$\Delta(B-V)$	$\Delta(U-B)$
J.D. 2444163		
0.828	$-0\overset{\mathrm{m}}{.}039$	$-0\overset{\mathrm{m}}{.}194$
0.847	−0.054	−0.133
0.869	−0.039	+0.050
0.884	−0.064	−0.128
0.917	−0.063	−0.174
0.936	+0.041	−0.229
0.962	+0.037	−0.141
0.977	−0.048	−0.040
0.989	−0.039	−0.034
0.006	−0.037	−0.224
0.021	−0.035	−0.159
J.D. 2444517		
0.015	−0.043	−0.364
0.020	−0.099	−0.192
0.026	+0.031	−0.221
0.028	−0.030	−0.154
0.048	−0.009	−0.162
0.050	+0.007	−0.190
0.061	+0.029	−0.180
0.064	+0.012	−0.151
0.083	−0.084	−0.129
0.086	−0.132	−0.161
0.102	+0.026	−0.367
0.104	−0.087	−0.273
0.120	−0.045	−0.185
J.D. 2444554		
0.130	−0.092	−0.081
0.148	−0.075	−0.089
0.165	−0.061	−0.032
0.182	−0.049	−0.053
0.201	+0.006	+0.014
0.219	+0.061	−0.037
J.D. 2444895		
0.539	−0.018	−0.111
0.564	−0.035	−0.237
0.590	−0.030	−0.178
0.608	+0.011	−0.189
0.626	−0.011	−0.103
0.632	−0.031	−0.131
0.639	−0.014	−0.111
0.647	−0.007	−0.008
0.656	−0.020	−0.102
J.D. 2444895		
0.664	$-0\overset{\mathrm{m}}{.}031$	$-0\overset{\mathrm{m}}{.}158$
0.672	−0.054	−0.123
0.680	−0.034	−0.081
0.685	−0.033	+0.006
J.D. 2444908		
0.240	−0.012	−0.222
0.250	−0.028	−0.261
0.262	+0.005	−0.137
0.276	−0.007	−0.089
0.284	−0.047	−0.047
0.293	−0.017	−0.097
0.304	−0.012	−0.023
0.309	−0.055	+0.071
0.318	−0.007	+0.052
0.326	−0.007	+0.001
J.D. 2444935		
0.632	−0.066	−0.028
0.640	−0.040	−0.043
0.648	−0.034	−0.076
0.655	−0.002	−0.069
0.660	−0.035	−0.023
0.666	−0.036	+0.043
0.674	−0.022	−0.008
0.683	0.000	+0.013
0.691	−0.034	−0.005
0.698	−0.060	−0.006
0.707	−0.029	−0.082
0.716	−0.014	−0.138
J.D. 2445261		
0.372	−0.042	+0.003
0.387	−0.005	−0.027
0.395	−0.014	−0.079
0.410	−0.034	−0.094
0.431	−0.034	−0.086
0.443	−0.074	−0.052
0.452	+0.006	−0.039
0.462	−0.019	−0.091
0.473	−0.016	−0.111
0.485	−0.033	−0.103
0.496	−0.035	−0.055
0.509	−0.047	+0.042
0.625	−0.047	−0.023

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remained almost neglected from the photoelectric observations, and whatever photoelectric observations are available in the literature, they indicate that the given photometries of δ Cap are unsatisfactory. Using the ephemeris given in GCVS (1969), the secondary minimum is found to be considerably shifted from its expected position, which fact is in contradiction with the findings of Dorren *et al.* (1980) that the secondary minimum appears to occur close to 0.50 phase. An improved period of $1\overset{d}{.}022766$ has been presented, which is slightly less than the adopted period. The duration of both minima have been given. The duration of secondary minimum has been given for the first time. The duration of primary minimum comes out to be more than double given in the finding lists of binary stars of 1963 and 1980. The duration of secondary minimum comes out to be less than the duration of primary minimum. Unequal shifts of minima and their unequal durations are found, which are indicative of the presence of eccentricity, which has been neglected by Crump (1921), but has been suspected by Stewart (1958), however, no quantitative assessment has been given for the eccentricity in this communication. The branches of minima are slightly asymmetric and are attributed to the effect of gas streams rather than to the effect of ellipticity as suggested by Ohmori (1981), because the light outside eclipse does not provide evidence of changing light curvature. Unequal heights at quadratures or maxima support this contention. The depressions of the order of $0\overset{m}{.}1$ on both sides of primary minimum are found, which are thought to be caused by the presence of disc rather than a shell or extended atmosphere. The photometric colour indices and spectral-luminosity types of δ Cap have been presented for the first time, assuming the primary eclipse to be a total occultation. The spectral type of secondary component was not traceable in the literature. The present spectral type of the primary component is quite consistent with that assessed by Dorren *et al.* (1980), however, the ratio of depths of minima do not agree with the present spectral type of the secondary component, although the $B - V$ colour index of comparison star comes out to be equal to the one given in the *Arizona Tonantzintla Catalogue*, and depths appear to be reliable. However, the ratio of depths of minima are consistent with the assessment of Dorren *et al.* (1980) that the secondary component is considerably fainter than the primary component. Probably, the complications present in the light curves or else, some unknown source contributing complications may be responsible for such discrepancy. However, present spectral types are consistent in the sense that the spectral type of the maximum lies between the spectral type of the components. The $\Delta(B - V)$ and $\Delta(U - B)$ colour indices show variations throughout the cycle, however, the behaviour of colour variations is not symmetric in the light of the behaviour of colour variations, and considering their positioning of light variations, characteristics and spectral types, the possibility of intrinsic variability has been negated, which fact is in contradiction to Dorren *et al.* (1980). Two dips around phases 0.20 and 0.67 are noted. The dips around phase 0.20 appears to be a distortion wave minimum like feature, which is caused by the movement of cool spots, and is in the light of Srivastava's (1987) declaration that δ Cap is a RS CVn binary. The present observations do not definitely establish this feature as the observations between phases 0.72 to 0.82 are lacking; however, they show an increasing trend like that of wave

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maximum just after $0^p.70$. Considerably large scatter is present at the tip of secondary minimum which suggests that primary component is responsible for this scatter. The maximum around fourth contact of primary minimum is higher than the maximum around first contact, which is thought to be caused by gas streaming. Previously found signatures of sudden period change (Srivastava, 1987), changing depth of primary minimum, non-systematic colour variations, uncompromising spectral type of the secondary component, large scatter present in δ Cap and indication of little ultraviolet excess suggest that stellar activity and mass exchange may be present in the system; however, direct evidences from the spectrophotometric and new spectroscopic observations are yet to come. Unfortunately, the last spectroscopic observations were published long back in 1961. Since then two decades have elapsed and perhaps the system's behaviour may have taken a new turn. It appears definite that the light curve of δ Cap is variable. The disc is found to be associated with the primary component.

New photometric and spectroscopic observations and observations in other frequencies are badly needed for δ Cap in order to unfold some more mysteries of this interesting system, and also to confirm the facts given in this paper.

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