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Eclipsing binary research at Uttar Pradesh State Observatory

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Abstract. A resume of the research works carried out by various scientists, at the Uttar Pradesh State Observatory, Naini Tal, in the field of eclipsing variables between 1956 and 1988 is given.

Key words : Uttar Pradesh State Observatory—eclipsing binaries

1. Introduction

Studies in the field of eclipsing binary stars started at the Observatory as early as 1956 with the spectrographic study of Wolf-Rayet eclipsing binary HD 214419 (observations of which had been made using Mount Wilson 60-inch reflector). However, the photoelectric photometry of bright eclipsing systems commenced in the year 1957-58 on 10-inch Cooke refractor using *B*, *V* and interference filters. Some of the stars selected for observations were eclipsing binaries HD 214419, HD 193576 (Wolf-Rayet) and β Lyr, δ Ori and AR Cas. Some of the early publications are by Bappu (1957) and Bappu & Sinvhal (1959). The first paper deals with the physical conditions in Wolf-Rayet atmospheres and the second pertains to interference filter photometry of weak emission lines in CQ Cephei. This paper states that photoelectric photometry using narrow pass-band interference filters is a powerful technique for the study of emission line intensity variations of stars even with small telescopes. The photoelectric *B* and *V* observations, during primary minima of long period eclipsing binary 32 Cyg, were published by Chandra & Pande (1960), who reported the light curve and colour of the two components. The complete light curves in *B* and *V* filters of IM Mon eclipsing system were published by Sanyal, Mahra & Sanwal (1965), who studied the period of the system and attributed the asymmetry in the light curve to the intrinsic variability of one of the components.

Since 1964 systematic studies of eclipsing binary systems have been undertaken with a view to securing their complete light curves in *U*, *B* and *V* filters of Johnson and Morgan system and analysing the light curves for determining the geometric elements. Most of the eclipsing binaries selected for this purpose were those for which spectroscopic elements were available in the literature. The aim was to obtain the absolute elements namely masses and radii of the systems.

2. Photometric study

ZZ Cephei is the first eclipsing system for which geometrical elements and absolute dimensions were determined by Kandpal & Srivastava (1967) using *V* light of the system.

There are 39 eclipsing systems which have since been observed at the U.P. State Observatory and results published. These binaries are listed in table 1. Table 1 contains the name of the star, spectral type, R.A. and Dec. (1950), maximum and minimum magnitudes of the system, period and references. We notice that XX Cas and GG Cas are the faintest ($10\text{-}10^m.7$) eclipsing binaries observed with the 38-cm reflector using uncooled 1P21 photomultiplier and d.c. techniques. Some of the observed peculiarities among these studied systems are as follows. (i) flares have been detected in the star AR Lac during the primary eclipse; (ii) intrinsic light variability of the hotter component in MM Cas has been found; (iii) primary component of DI Peg is surrounded by a disc of circumstellar material.

3. Spectrophotometric study

Another program that is being pursued at the Observatory is that of spectrophotometric studies of binary stars.

The binary stars observed spectrophotometrically are listed in table 2. Observations of seven systems have been published. All the systems have been observed with the 104-cm reflector telescope. Mostly bright stars have been observed except for GG Cas which is a tenth magnitude star.

Table 1. List of binary stars observed at UPSO with UBV photoelectric photometer

Sl No.	Star name & Sp-types	α 1950 δ 1950	Magnitudes & period	References*
1.	DX Aqr A2 V	$21^h\ 59^m\ 43^s$ $-17°\ 24'.4$	$6^m.4\text{-}6^m.8$ $0^d.4617$	R. K Srivastava & B K. Sinha, ASS **111**, 225 (1985); R. K Srivastava, ASS, **113**, 333, (1985)
2.	EE Aqr FO	22 31 59 −20 07.1	8.3-8.9 0.5090	R. K Srivastava, *ASS* **62**, 477 (1979).
3.	UW Boo FO	14 19 07 −47 20.4	10.4-11.1 1.0047	J. B Srivastava & C. D. Kandpal, *ASS* **133**, 291 (1987).
4	AE Cas G6 + K4	01 23 17 +69 52.0	11.9-12.9 0.7591	J. B Srivastava & C. D Kandpal, *AA* **34**, 281 (1984)
5.	CC Cas 09 + 09	03 10 07 +59 22.6	7.1-7.3 3.3688	J. B. Srivastava, *IBVS* 1571 (1979).
6.	GG Cas B3 + KO	01 13 07 +56 03.9	9.9-10.3 3.7587	J. B. Srivastava & C D Kandpal, *BAC* **21**, 345 (1970)
7.	MM Cas F3 + G9	00 53 54 +54 23.0	11.8-12.9 1.1585	U. S. Chaubey, *IBVS* 2348 (1983). U. S. Chaubey & M. Singh, *BASI* **12**, 40 (1984).
8.	TW Cas B9 + AO	02 41 44 +65 31.0	8.3-9.0 1.4283	C. D. Kandpal, *ASS* **32**, 291 (1975).
9.	XX Cas B4 + B6	01 26 16 +60 42.6	10.0-10.7 3.0672	R K. Srivastava, *ASS* **92**, 149 (1983), *IBVS* 3001 (1987).
10.	V364 Cas A6 + A9	00 52 06 +50 25.0	10.6-11.4 1.5431	U. S. Chaubey & M. Singh, *BASI* **12**, 40 (1984); U. S. Chaubey *ASS* **106**, 273 (1984).

(Continued)

Table 1. (Continued)

Sl No	Star name & Sp-types	α 1950 δ 1950	Magnitudes & period	References*
11	AS Cam B8 + B9	05 24 16 +69 27.4	8 6-9 2 3 4310	T D Padalia & R K Srivastava, *ASS* **38**, 87 (1975)
12	AY Cam GO	08 19 17 +77 22.8	9 7-10.3 2 7350	J B. Srivastava & C D Kandpal, *IBVS* 3005 (1987)
13	δ Cap A7m III	21 44 17 −16 21.3	2 8-3 1 1 0228	R K Srivastava, *IBVS* 3008 (1987)
14.	RS CVn F4 + KO	13 08 18 +36 12.0	7.9-9.1 4 7979	R K Srivastava *ASS* 137, 63 (1987), J B. Srivastava & C D Kandpal, *ASS* **163**, 217 (1990)
15.	EI Cep Am + F1	21 28 43 +76 11 0	7 5-8 1 8 4393	T D Padalia & R K Srivastava, **32**, 285 (1975)
16	WX Cep A2 + A5	22 29 33 +63 15.9	8.7-9 3 3 3784	C D Kandpal & J B Srivastava *BAC* **21**, 345 (1970)
17	XY Cep B8 + AO	23 50 06 +68 39.4	10 1-10.9	J B. Srivastava *ASS* **66**, 143 (1979)
18.	ZZ Cep B7 + FOV	22 43 23 +67 52.2	8 6-9 6 2.1418	C D. Kandpal & J. B Srivastava *BAC* **18**, 265 (1967)
19	RW Cet	02 12 50 −12 26.5	10 4-11.4 0 9752	T D Padalia, *ASS* **159**, 413 (1987)
20.	XY Cet Am + Am	02 56 57 +03 19.2	8.7-9.5 0.7807	R. K. Srivastava & T. D Padalia, *ASS* **38**, 79 (1975)
21	32 Cyg KS + B4	20 13 55 47 33.6	3.9-4 1 1147.4	S. Chandra & M. C. Pande, *Observatory* **80**, 146 (1960)
22.	BZ Eri F2	04 09 45 −06 09 2	9-9.5 0.6642	R. K. Srivastava & B. K Sinha, *IBVS* 1919 (1981); R. K. Srivastava, *IBVS* 2806 (1985); R K. Srivastava & Wahab Uddin *ASS* **126**, 105 (1986).
23.	CD Eri AO	03 45 21 − 08 45 9	9.5-10.5 2.8767	C. D. Kandpal & J. B. Srivastava, *ASS* **67**, 213 (1980)
24.	RZ Eri A5 + G8IV	04 41 24 − 10 46 5	7.7-8.7 39.2824	J. B. Srivastava & C. D. Kandpal, *ASS* **147**, 355 (1988).
25	WX Eri A5 + KO	03 21 50 00 52.8	9.5-10.5 0.8233	J. B Srivastava & C. D. Kandpal, *ASS* **121**, 251 (1987).
26	AV Hya A1	09 32 25 + 5 32.6	10.2 + 10.8 0.6834	J. B Srivastava & C. D. Kandpal, *ASS* **76**, 173 (1981).
27.	VZ Hya F5 + F5	08 29 13 −06 08.9	9.2-9.7 2.9043	T. D. Padalia & R. K. Srivastava, *ASS* **35**, 249 (1975).
28.	AR Lac F8 + KO	22 06 40 +45 29.8	6.1-6.8 1.9832	R. K. Srivastava, *ASS* **78**, 173 (1981); *IBVS* 2459 (1981) *IBVS* 271 (1985).
29.	TX Leo A2	10 32 25 +08 54.6	5.7-5.8 2.44451	J. B. Srivastava & C. D. Kandpal, *BAC* **19**, 381 (1968).

(Continued)

Table 1. (Continued)

Sl No	Star name & Sp-types	α 1950 δ 1950	Magnitudes & period	References*
30	AO Mon B3 + B5	7 4 8 −04 33 0	9.6-10 2 1 8847	C D Kandpal, *ASS* **40**, 3 (1976).
31	IM Mon B5Vp + B7	06 20 32 −03 15 0	6 4-6.5 1 1902	A Sanyal & S D Sinvhal, *Observatory*, **84**, 211 (1964), A Sanyal, H S. Mahra & N B. Sanwal, *BAC* **16**, 209 (1965).
32	DI Peg F3 + KO	23 29 43 +14 41 6	9 4-10 4 0 7118	U S Chaubey, *ASS* **81**, 283 (1982)
33.	GH Peg A3	21 48 28 +15 02 4	8 8-9.3 2 5561	R K Srivastava & T D. Padalia, *ASS* **29**, 435 (1974).
34	IZ Per B8	01 28 56 +53 45.7	7 8-9.0 3 6877	R K Srivastava & T D Padalia, *BAC* **21**, 359 (1970).
35	RT Per F2	03 20 12 +46 23 9	10 5-11.7 0 8494	B B. Sanwal & U S Chaubey, *ASS* **75**, 329 (1981)
36	ST Per A3 + G-K	02 56 54 +38 59 6	9 5-11.4 2.6483	R K Srivastava *BAC* **21**, 219 (1970)
37	CD Tau F7 + F5	05 14 33 +20 04 8	6 8-7.3 3 4351	J B Srivastava, *ASS* **40**, 15 (1976).
38	AW UMa FO-F2	11 27 26 +30 14 6	6.8-7 1 0 4387	R K. Srivastava & T. D. Padalia, *ASS* **120**, 121 (1986)
39.	W Uma F8	9 40 15 +56 10 9	7.8-8.5 0 3336	S. C. Joshi, *BAC* **17**, 31 (1966).

**ASS—Ap Sp Sci*, *AA—Acta Astr*, *BAC—Bull. Astr. Inst. Czech.*; *BASI—Bull. Astr. Soc. India.*

Table 2. List of binary stars observed at UPSO with spectrophotometer

Sl No	Star name Sp-types	α 1950 δ 1950	Magnitudes & periods	Wavelengths (μm)	References
1	KX And B3e + K	23^h 04^m 51^s $+49°$ $55'.3$	$7^m 0$-$7^m 1$ $38^d.908$?	320-780	P S Goraya, M Singh & U S Chaubey, *IBVS* 2519 (1984)
2	GG Cas B3 + KO	01 15 36 +56 17	10 3-10 9 3 7587	320-760	U. S Chaubey & M. Singh, *ASS* **151**, 335 (1989).
3	RZ Cas A1 + G6	2 48 01 +69 36.2	6.3-7.9 1.1952	300-800	U. S. Chaubey (in preparation)
4.	δ Cap A8	21 46 30 −16 10 0	2.9-3 1 1 0826	330-730	R. K Srivastava, J. B. Srivastava & S. C Joshi, *ASS* **143**, 107 (1988).
5	AR Lac F8 + KO	22 08 18 +45 40.2	6.1-6 8 1.9832	320-780	U. S. Chaubey & M Singh, *ASS* **166**, 177 (1990); P. S Goraya & R. K. Srivastava, *IBVS* 2579 (1984).
6.	β Lyr B7 + A5	18 49 42 +33 21.0	3.4-4.2 12.9370	320-800	M. Singh & U. S. Chaubey, *ASS* **129**, 251 (1987).
7.	V711 Tau G5 + K	03 34 13 +10 25.5	5 7-5.9 2.8378	330-710	S. C Joshi, R. K. Srivastava & J. B. Srivastava, *ASS* **152**, 85 (1989).

Orbital elements

Orbital elements of the systems are given in table 3 The table gives inclination of the orbit, fractional radii of the components, method of analysis of the light curves, and references. Twenty-six binaries have been analysed for geometrical elements Seventeen stars have been analysed by Russell & Merrill method. Rest of them have been analysed using Kopal's frequency domain method

Table 3. Orbital elements of eclipsing binary stars determined at UPSO

Sl No	Stars name	Orbital elements	Method of light curve analysis	References
1	EE Aqr	i = 64° 2 rh = 0 402 rc = 0 361	RM	T D Padalia, *ASS* **62**, 477 (1979)
2	GG Cas	i = 74° 5 rh = 0 116 rc = 0 357	Kopal	U S Chaubey, *BASI* **12**, 237 (1984)
3	TW Cas	i = 88° 2 rh = 0 332 rc = 0 222	RM	C D Kandpal, *ASS* **32**, 291 (1975)
4	XX Cas	i = 84° 2 rh = 0 271 rc = 0 372	RM	R K Srivastava, *IBVS* 3001 (1987)
5	AE Cas	i = 80° 4 rh = 0 356 rc = 0 345	Kopal	J B Srivastava & C D Kandpal, *ASS* **34**, 281 (1984)
6	V364 Cas	i = 87° 1 rh = 0 221 rc = 0 196	Kopal	U. S Chaubey, *ASS* **106**, 273 (1984)
7	EI Cep	i = 86° 3 rh = 0.096 rc = 0.107	RM	T D Padalia & R K Srivastava, *ASS* **32**, 291 (1975)
8.	ZZ Cep	i = 88° 5 rh = 0 248 rc = 0.200	RM	C D Kandpal & J B Srivastava, *BAC* **18**, 265 (1967)
9	WX Cep	i = 84° 6 rh = 0.185 rc = 0.228	Kopal	U S Chaubey, *BASI* **12**, 237 (1984)
10.	XY Cep	i = 75° 6 rh = 0 184 rc = 0.307	RM	J B Srivastava, *ASS* **66**, 143 (1979)
11.	XY Cet	i = 87° 5 rh = 0.171 rc = 0.129	RM	R. K. Srivastava & T D Padalia, *ASS* **38**. 79 (1975).
12.	UZ Cyg	i = 84°.7 rh = 0.066 rc = 0.201	Kopal	U S. Chaubey, *BASI* **12**, 237 (1984).

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Table 3. (Continued)

Sl No	Stars name	Orbital elements	Method of light curve analysis	References
13	VW Cyg	i = 87°.1 rh = 0.102 rc = 0 238	Kopal	U S. Chaubey, *BASI* **12**, 237 (1984)
14	CD Eri	i = 72° 0 rh = 0.178 rc = 0.371	RM	C D Kandpal & J. B Srivastava, *ASS* **67**, 213 (1980)
15	AV Hya	i = 70° 7 rh = 0.337 rc = 0.406	RM	J B Srivastava & C D Kandpal, *ASS* **76**, 173 (1981).
16	VZ Hya	i = 89°.4 rh = 0 101 rc = 0.112	RM	T. D Padalia & R. K Srivastava, *ASS* **35**, 349 (1975)
17	AR Lac	i = 83° 5 rh = 0 169 rc = 0 336	Kopal	R K Srivastava, *AA* **34**, 291 (1984)
18	TX Leo	i = 66°.8 rh = 0 29 rc = 0 18	RM	J B Srivastava & C D Kandpal, *BAC* **19**, 381 (1968).
19	AO Mon	i = 85° 6 rh = 0 264 rc = 0 246	RM	C. D. Kandpal, *ASS* **40**, 3 (1976).
20	AQ Peg	i = 86° 6 rh = 0 188 rc = 0 242	Kopal	U S Chaubey, *BASI* **12**, 237 (1984).
21	GH Peg	i = 82° 4 rh = 0.139 rc = 0.169	RM	T. D Padalia & R K Srivastava, *ASS* **32**, 285 (1975)
22	DI Peg	i = 82° 3 rh = 0.318 rc = 0.309	RM	U. S. Chaubey, *ASS* **81**, 283 (1982)
23.	IZ Per	i = 87°.0 rh = 0.19 rc = 0.23	RM	R K Srivastava & T D Padalia, *BAC* **21**, 359 (1970)
24	RT Per	i = 84°.6 rh = 0.227 rc = 0.291	RM	B B. Sanwal & U. S Chaubey, *ASS* **75**, 329 (1981).
25	ST Per	i = 86°.9 rh = 0.215 rc = 0.249	Kopal	U. S. Chaubey, *BASI* **12**, 237 (1984).
26.	CD Tau	i = 87°.8 rh = 0.135 rc = 0.115	RM	J. B. Srivastava, *ASS* **40**, 15 (1976).

5. Absolute dimensions

Masses and radii have been calculated for 18 binaries, nine of which are detached and the others semi-detached (table 4) Using our derived absolute dimensions, the evolutionary status of these binaries has been discussed. Our main conclusions are that (i) the cooler components in semi-detached binaries are being over-luminous for their spectral types and larger than the ZAMS stars of equal mass; and (ii) the cooler componnet of GG Cas displays significant underluminosity compared to a ZAMS star of the same mass

6. Period studies and mass transfer

Table 5 lists 20 stars for which period study has been made. Columns two and three give the period and the number of observations used for this study, and the last column gives the references. Period variations have been noticed in all the systems except V364 Cas, EI Cep, and XY Cet

Using the observed times of minimum light derived from the photometric observations, the mass loss and the mass transfer rates have been computed for seven binary systems, namely TV Cas, SW Cyg, V444 Cyg, CQ Cep, AR Lac, and DI Peg. On the basis of the computed mass transfer rates in TV Cas and SW Cyg, Chaubey (1985) has concluded that (i) the Roche-lobe of the secondary components in Algols are shrinking as mass transfer proceeds; (ii) the average mass transfer in Algols corresponds to the thermal time scale of the mass losing star; and (iii) the orbital angular momentum is not conserved during the mass transfer.

7. Statistical studies

Period-mass ratio relations for eclipsing binaries with periods not exceeding five days have been given by Sinvhal & Srivastava (1978). Chaubey (1979) has given empirical relations between systemic mass and orbital angular momentum. It has been found that for the same mass, a semi-detached binary system has greater orbital angular momentum than a contact binary and less than a detached system. For this study, 91 binaries have been considered. Gravitational radiation and spiralling time relations for close binary systems have been given by Padalia (1987, 1988).

8. Origin and evolution

On the basis of nonconservation of orbital angular momentum, Chaubey (1980) studied the evolutionary processes in semi-detached binary stars. It is found that all the semi-detached binary stars originated through case B mass transfer. Further, Chaubey (1984) has also examined 333 double lined spectroscopic binaries in the bilogarithmic plots of M vs A with respect to the critical separtion A_{AB} and A_{BC} and noted that binary stars having separations corresponding to case A evolution cannot form.

9. Present and future programs

It is proposed to reanalyse some of the above mentioned observations of eclipsing binaries by Wood's method for more accurate results. The present program of observing

RS CVn systems through UBV filters for obtaining complete light curves will continue. Spectrophotometry of bright RS CVn's will also continue. The purpose is to have monochromatic light curves and detect the presence of H_α and Ca II emission lines and note their variations over a long period of time to elicit stellar activity cycles.

Table 4. Absolute elements of eclipsing binary stars determined at UPSO

Sl No	Star name	Masses in solar units	Radii in solar units	Evolutionary states	References
1	GG Cas	mh = 4 35 mc = 3 44	Rh = 2 34 Rc = 7 26	sd	U S Chaubey, *BASI* **12**, 237 (1984)
2	IW Cas	mh = 4 07 mc = 1 44	Rh = 3 11 Rc = 2 08	d	C D Kandpal, *ASS* **32**, 291 (1975)
3	V364 Cas	mh = 1 92 mc = 1 61	Rh = 1 84 Rc = 1 67	d	U S Chaubey, Ph D thesis (1985)
4	EI Cep	mh = 1 7 mc = 1 8	Rh = 1 8 Rc = 2 5	d	T D Padalia & R K Srivastava, *ASS* **32**, 291 (1975)
5	ZZ Cep	mh = 4 1 mc = 1 9	Rh = 3 2 Rc = 2 5	d	C D Kandpal & J B Srivastava, *BAC* **18**, 265 (1967)
6	WX Cep	mh = 1 10 mc = 1 10	Rh = 2 51 Rc = 3 73	d	U S Chaubey, *BASI* **12**, 237 (1984)
7	XY Cep	mh = 3 8 mc = 1 1	Rh = 2 7 Rc = 4 6	sd	J B Srivastava, *ASS* **66**, 143 (1979)
8	XY Cet	mh = 1 76 mc = 1 63	Rh = 2.14 Rc = 1 61	d	R K Srivastava & T D Padalia, *ASS* **38**, 79 (1975)
9	UZ Cyg	mh = 3 42 mc = 0 31	Rh = 4 25 Rc = 13 02	sd	U S Chaubey, *BASI* **12**, 237 (1984)
10	VW Cyg	mh = 2 65 mc = 0 53	Rh = 2 61 Rc = 6 01	sd	U S Chaubey, *BASI* **12**, 237 (1984)
11	AR Lac	mh = 1 41 mc = 1 42	Rh = 1 12 Rc = 2 19	sd	R. K Srivastava, *BASI* **12**, 52 (1984).
12	TX Leo	mh = 2 4 mc = 0 9	Rh = 3.4 Rc = 1.4	d	J B Srivastava & C D. Kandpal, *BAC* **19**, 381 (1968)
13	AO Mon	mh = 5.53 mc = 5.25	Rh = 3.53 Rc = 3 28	d	C D Kandpal, *ASS* **40**, 3 (1976).
14	AQ Peg	mh = 2 81 mc = 0 57	Rh = 2 74 Rc = 4.79	sd	U S. Chaubey, *BASI* **12**, 237 (1984).
15	DI Peg	mh = 1.48 mc = 0 70	Rh = 1 34 Rc = 1.37	sd	U. S Chaubey, *ASS* **81**, 283 (1982)
16	RT Per	mh = 1 15 mc = 0 33	Rh = 1 45 Rc = 1.85	sd	B. B Sanwal & U S Chaubey, *ASS* **75**, 329 (1981)
17	ST Per	mh = 2.62 mc = 0 40	Rh = 2 2 Rc = 2.6	sd	U S Chaubey *BASI* **12**, 237 (1984).
18	CD Tau	mh = 1 4 mc = 1 3	Rh = 1.8 Rc = 1.5	d	J B. Srivastava, *ASS* **40**, 15 (1976).

Table 5 List of binary stars whose period variability has been studied

Sl No	Name of stars	Year of observations	No of observations	References
1	EE Aqr	1940-1985	82	R K Srivastava, *ASS* **129**, 221 (1987)
2	DX Aqr	1959-1981	27	R K Srivastava *ASS* **124**, 397 (1986)
3	δ Cap	1971-1980	17	R K Srivastava, *IBVS* 3008 (1987)
4	GG Cas	1927-1980	12	R K Srivastava, *ASS* **132**, 331 (1987)
5	TV Cas	1900-1977	315	U S Chaubey, *ASS* **63** 247 (1979)
6	V364 Cas	1930-1980	31	U S Chaubey, *ASS* **106**, 273 (1984)
7	XX Cas	1922-1983	38	R K Srivastava, *ASS* **127**, 345 (1987)
8	CQ Cep	1899-1982	36	M Singh, U S Chaubey, *ASS* **124**, 389 (1986)
9	EI Cep	1900-1970	9	R K Srivastava *ASS* **135**, 229 (1987)
10	XY Cet	1932-1977	25	R K Srivastava, *ASS* **150**, 173 (1988)
11	RW Com	1900-1984	231	R K Srivastava, *ASS* **139**, 373 (1987)
12.	SW Cyg	1880-1978	174	U S. Chaubey, *ASS* **67**, 129 (1980)
13	V444 Cyg	1957-1981	15	M Singh & U S Chaubey, *ASS* **124**, 389 (1986)
14.	BZ Eri	1928-1981	38	R K Srivastava, *ASS* **129**, 409 (1987)
15.	VZ Hya	1918-1979	19	R K. Srivastava, *ASS* **133**, 71 (1987)
16.	AR Lac	1900-1975	127	R K Srivastava, *BASI* **12**, 52 (1984)
17	DI Peg	1957-1980	37	U S. Chaubey, *ASS* **81**, 383 (1982).
18.	GH Peg	1931-1984	10	R K Srivastava, *ASS* **134**, 177 (1987)
19.	IZ Per	1928-1983	16	R K. Srivastava, *ASS* **129**, 143 (1987)
20.	ST Per	1908-1988	95	R. K Srivastava, *ASS* **143**, 175 (1988)

The Observatory has already acquired a Micro-VAX II system and a Photometrics Inc. CCD (chip dimensions: 384-576 pixel, pixel size 23 μm $\times$ 23 μm which will greatly help in extending this field of research to fainter stars. Also there is a proposal in the eight national plan to acquire a reticon array based fast spectrum scanner which also would help us to carry out studies of energy distribution and spectra of stars with better temporal resolution in case of binaries containing cataclysmic variables as one of the components.

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Discussion

Pandey : According to Ziolkowski, Algols having mass greater than 5 $M_\odot$ are remnants of case A mass transfer. What are your comments regarding this?

Chaubey : The terms Case A, Case B and Case C are based on the evolutionary stages of the massive primary in which it fills its Roche-lobe and depend on initial separations between the systemic components. An examination of 333 double lined spectroscopic binaries, which are the progenitors of Algols and represent the stage prior to mass exchange, in mass-semimajor axis plane with respect to the critical separation A_{AB} indicates a strong deficit of binaries in the whole mass range [Chaubey (1984) *Ap. Sp. Sci.* **103**, 385]. In our opinion, the binary stars having separations corresponding to case A evolution cannot form in the whole mass range.

Kaul : (1) How do you tackle the problem of Gibbs oscillations in α functions using Hankel transforms: (2) Why error analysis has not been employed in arriving at moments of the light curve? (3) How is it that photometric perturbations effects given by Kopal and not by H. J. Livaniou, have been employed as they again do not converge?

Chaubey : In order to analyse the light curves by Kopal's Frequency domain method we have followed the procedure as given by Kopal [*Ap. Sp. Sci.* **82** (1982), 123. 444].

Saha : You said, during the evolution of binary stars orbital angular momentum is not conserved. What about the total angular momentum? Whether it is conserved or not?

Chaubey : When we take stellar models which are in contact like W UMa type stars and assume that the stars are rotating synchronously with orbital motion, then the rotational angular momentum $J = j_1 + j_2$ can be neglected because $j_1 = M_1 k_1^2 R_1^2 \omega$, where M_1 and R_1 are mass and radius of the component and k_1 is radius of gyration in units of R_1. According to L. Motz [*Ap. J.* **115** (1952), 562] for a main-sequence star $k^2 \cong 0.06$ and for an evolved star $k^2 \leqslant 0.01$. From Rocke model one can get,

$$j_1/H = 0.21\ k^2\ (1+q)^{1/3} q^{2/3}$$

$$\approx 0.02 \text{ for main sequence star,}$$

$$\approx 0.005 \text{ for evolved star}$$

Hence $J/H \approx 0.02$,

where H is total orbital angular momentum. It means our investigated relations between H and M are same as $\mathcal{L}$ and M where $\mathcal{L} = H + J$. Therefore during the evolution, if a detached binary system becomes semi-detached or contact, its total angular momentum decreases. Perhaps, some part of it is consumed in pumping the tidal distortions of the systemic components.