42. COMMISSION DES ETOILES DOUBLES PHOTOMETRIQUES

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INTRODUCTION

In this report literature and information received up to the beginning of November 1960 will be dealt with. I must thank those members of the Commission and other astronomers who have sent me reprints of their papers and who have, in reply to my request of August 1960, sent me information about work completed and in progress.

In accordance with a resolution adopted by the Commission at the Moscow meeting, a running bibliography of eclipsing binaries has been prepared. Up to November 1960 two mimeographed issues have been distributed to members of the Commission and to other astronomers working in this field. Special thanks are due to the compilers of the bibliography—Dr H. Schneller (German literature), Professor A. Fresa (Italian), Mrs K. Gordon Kron (North American), Dr A. Shulberg (Russian). The literature of the remaining countries was dealt with by myself, but this section of the bibliography has been taken over by Dr L. Plaut for future issues. Dr J. E. Merrill, Secretary of the Commission, has taken care of the reduplication and distribution of the bibliography.

Before commencing a detailed report on progress in the field of eclipsing binaries, it is proper to signalize the appearance of two major publications in this field. While L. Binnendijk's *Properties of Double Stars* (**1**) deals with binary stars in general, a large part of the book is devoted to the theory and observation of eclipsing binaries. It forms indeed a most useful advanced textbook on the subject. Z. Kopal's *Close Binary Systems* (**2**) is a more specialised treatise; it contains the most complete treatment that has yet appeared of many aspects of close binary systems and will be referred to often in the course of this report. S. Gaposchkin's chapter on 'The Eclipsing Binaries' (**3**) in the *Handbuch der Physik* provides a very useful summary of theory and observational data.

OBSERVATIONAL TECHNIQUES AND NEW PHOTOMETRIC DATA

Photo-electric equipment has been described by Abrami (**4**), Cocito and Masani (**5**) and Pinto (**6**). M. K. Vainu Bappu is preparing to initiate photo-electric observations of eclipsing binaries at Kodaikanal Observatory, of which he is now Director. Three-colour (*UBV*) photo-electric observations, mainly with a 60 cm Cassegrain reflector, were started recently at the Vatican Observatory.

Table 1 is a continuation of Table 1 on page 620 of *Trans. IAU* **10.** There has been an appreciable increase of activity in this field, judging by the number of references in the table (186, as compared with 144 in the previous report), although the number of stars observed is not much increased (from 103 to 110). There is still ample room for more observations. For example, of the 27 systems that were listed in Table 2 (*Trans. IAU* **10,** 622) as being in need of photo-electric observations, only five are reported in the present table; and only one of the

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thirteen listed in Table 3 (*Trans. IAU* **10,** 623). Popper (7) has published a list of thirteen double-lined eclipsing binaries needing good light-curves, together with a further list of sixteen found by him to show lines of both components. Only one star in the first list, and three in the second, are to be found in Table 1.

Table 1. New photo-electric observations

Star	References
AB And	Binnendijk, *Astr. J.* **64,** 69, 1959.
BX And	Chou, *Astr. J.* **64,** 469, 1959.
o And	Schmidt, *Z. Ap.* **48,** 249, 1959.
OO Aql	Kwee, *B.A.N.* **14,** 131, 1958.
V 822 Aql	Nicolini (Capodimonte).
FU Ara	Cillié and Lindsay, *M.N.R.A.S.* **121,** 333, 1960.
RR Ari	Archer, *J. Brit. astr. Ass.* **69,** 161, 1959.
SX Aur	Plavec (Ondrejov, two colours): Lavrov, *Bull. Obs. astr. Kazan* 35, 69, 1960.
WW Aur	Broglia and Lenouvel, *Mem. Soc. astr. Ital.* **30,** 201, 1959; Chou, *Astr. J.* **64,** 471, 1959.
BF Aur	Plavec (Ondrejov, two colours).
β Aur	Sinvhal (Naini Tal).
ϵ Aur	Thiessen, *Z. Ap.* **43,** 233, 1957; Huruhata and Kitamura, *Tokyo astr. Bull.* 102, 1958; Larsson-Leander, *Ark. Astr.* **2,** 283, 1958; Widorn, *Mitt. Univ. Sternw. Wien* **10,** 3, 1959; Albo, *Publ. Tartu astr. Obs.* **33,** 303, 1960; Frederick, *Astr. J.* **65,** 97, 1960; Gyldenkerne, *Publ. Kbh. Obs.* (in press); Reuning (Flower and Cook Obs., infra-red).
ζ Aur	Tanabe and Nakamura, *Tokyo astr. Bull.* 96, 1957; Grant and Abt, *Ap. J.* **129,** 320, 1959; Larsson-Leander, *Ark. Astr.* **2,** 413, 1960; Gyldenkerne (Brorfelde); Reuning (Flower and Cook Obs., infra-red).
SU Boo	Broglia, *Mem. Soc. astr. Ital.* **31,** 107, 1960.
44i Boo	Kwee, *B.A.N.* **14,** 131, 1958; Prokofyeva, *Per Zvezdy* **12,** 249, 1959; Plavec (Ondrejov).
SZ Cam	Neff (Madison, four colours).
S Cnc	Kordylewski and Szafraniec, *Acta astr. Cracoviae,* **7,** 177, 1957.
RZ Cnc	Broglia and Lenouvel, *Mem. Soc. astr. Ital.* **30,** 203, 1960; Broglia (in press).
R CMa	Koch, *Astr. J.* **64,** 337, 1959; **65,** 326, 1960; Kitamura (Tokyo, three colours); Knipe (Union Obs.).
29 CMa	Pande (Naini Tal).
YY CMi	Kordylewski and Szafraniec, *Acta astr. Cracoviae,* **7,** 177, 1957.
RS CVn	Popper, *Ap. J.* (in press).
δ Cap	Hogg and F. B. Wood (Stromlo, three colours).
ST Car	F. B. Wood, *Astr. J.* **64,** 57, 1959.
RZ Cas	Kordylewski and Szafraniec, *Acta astr. Cracoviae,* **7,** 177, 1957; Archer, *J. Brit. astr. Ass.* **68,** 266, 1958; Broglia and Lenouvel, *Mem. Soc. astr. Ital.* **30,** 203, 1960; Plavec (Ondrejov).
TV Cas	Chou, *Astr. J.* **64,** 468, 1959.
TW Cas	Bappu and Sinvhal (Naini Tal).
XX Cas	Chou, *Astr. J.* **64,** 468, 1959.
AO Cas	Abhyankar, *Ap. J. Suppl.* **4,** 187, 1959; Koch, *Astr. J.* **65,** 127, 1960.
AR Cas	Botsula and Kostylev, *Bull. Obs. astr. Kazan* **35,** 34, 1960; Kron (Lick Obs.).
AZ Cas	Larsson-Leander, *Ark. Astr.* **2,** 347, 1959.
CW Cas	Broglia, *Contr. Oss. astr. Merate* 113, 1957.
DO Cas	Kwee, *B.A.N.* **14,** 131, 1958.
RR Cen	F. B. Wood and Somerville (Stromlo); Knipe (Union Obs.).
U Cep	Huffer and Code, *Astr. J.* **64,** 128, 1959; Broglia (Merate).

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Star	References
VV Cep	Herczeg, *Budapest Mitt.* **42,** 39, 1957; Larsson-Leander, *Ark. Astr.* **2,** 135, 1957; **2,** 301, 1959; Fredrick, *Sky and Telesc.* **18,** 132, 1959; ——, *Astr. J.* **65,** 628, 1960; Gyldenkerne (Brorfelde); Reuning (Flower and Cook Obs., infra-red).
VW Cep	Archer, *J. Brit. astr. Ass.* **68,** 269, 1958; Kwee, *B.A.N.* **14,** 131, 1958; Szczepanowska, *Acta astr. Cracoviae* **9,** 38, 1959; Rakosch, *Z. Ap.* **50,** 178, 1960; Kaltchaeyev, *Astr. Circ. U.S.S.R.* 210, 1960; Larsson-Leander, *Ark. Astr.* **2,** 547, 1961; Cester (Trieste).
XX Cep	Lavrov, *Per. Zvezdy* **12,** 21, 1957.
CQ Cep	Bappu and Sinvhal, *Observatory* **79,** 140, 1959.
CW Cep	Abrami and Cester (Trieste).
RZ Com	Broglia (Merate).
TZ CrA	F. B. Wood, *Astr. J.* **64,** 56, 1959; **65,** 23, 1960.
U CrB	Kordylewski and Szafraniec, *Acta astr. Cracoviae* **7,** 177, 1957; D. B. Wood, *Ap. J.* **127,** 351, 1958.
Y Cyg	Magalashvili and Kumsishvili, *Bull. Abastumani Astrophys. Obs.* 24, 1959; Plavec (Ondrejov).
GO Cyg	Kwee, *B.A.N.* **14,** 131, 1958; Mannino (Loiano).
MR Cyg	Hardie (Dyer Obs., three colours).
V 367 Cyg	Fresa (Capodimonte).
V 401 Cyg	Spinrad, *P.A.S.P.* **71,** 53, 1959.
31 Cyg	Larsson-Leander (Stockholm, two colours).
32 Cyg	Chandra and Pande, *Observatory* **80,** 146, 1960; Fresa, *Mem. Soc. astr. Ital.* (in press); Botsula (Engelhardt Obs.); Gyldenkerne (Brorfelde); Larsson-Leander (Stockholm, two colours).
DM Del	Schneller, *Astr. Nach.* **285,** 265, 1960.
RW Dor	Hogg (Stromlo, three colours).
AI Dra	Cester, *Mem. Soc. astr. Ital.* **30,** 287, 1960.
S Equ	Plavec (Ondrejov, two colours).
YY Eri	Kwee, *B.A.N.* **14,** 131, 1958.
AS Eri	Koch, *Astr. J.* **65,** 139, 1960; Cillié and Lindsay, *Mon. Not. astr. Soc. S. Afr.* **19,** 150, 1960.
Z Her	Kordylewski and Szafraniec, *Acta astr. Cracoviae* **7,** 177, 1957.
RX Her	Miczaika, *Astr. J.* **62,** 376, 1957.
SZ Her	Broglia (Merate).
TT Her	Westerhout (Leiden, 1951).
AK Her	Kwee, *B.A.N.* **14,** 131, 1958; Schmidt and Herczeg, *Z. Ap.* **47,** 106, 1959; Binnendijk (Flower and Cook Obs., two colours); Szczepanowska (Cracow).
NQ Her	Fichera (Capodimonte).
u Her	Kordylewski and Szafraniec, *Acta astr. Cracoviae* **7,** 177, 1957.
FG Hya	Binnendijk (Flower and Cook Obs., two colours).
SW Lac	Kwee, *B.A.N.* **14,** 131, 1958; Bookmyer (Flower and Cook Obs., two colours); Broglia (Merate).
CM Lac	Alexander, *Astr. J.* **63,** 106, 1958; Hardie (Dyer Obs.).
Y Leo	Johnson, *Ap. J.* **131,** 127, 1960.
UV Leo	Broglia (Merate); Szczepanowska (Cracow).
UZ Leo	Broglia and Lenouvel, *Mem. Soc. astr. Ital.* **30,** 205, 1960.
XY Leo	Koch, *Astr. J.* **65,** 374, 1960.
AM Leo	Abrami, *Mem. Soc. astr. Ital.* **30,** 303, 1960.
RS Lep	F. B. Wood, *Astr. J.* **64,** 57, 1959.
RR Lyn	Magalashvili and Kumsishvili, *Bull. Abastumani Astrophys. Obs.* 24, 1959; Botsula, *Bull. Obs. astr. Kazan* 35, 43, 1960.
β Lyr	Gordon, *P.A.S.P.* **71,** 526, 1959; Binnendijk, *Astr. J.* **65,** 85, 1960; D. B. Wood and Walker, *Ap. J.* **131,** 363, 1960; Fresa, *Mem. Soc. astr. Ital.* **31,** 365, 1960.
RW Mon	Batten, *Ann. Ap.* **20,** 103, 1957.

UX Mon	F. B. Wood, *Astr. J.* **62**, 327, 1957.
V 502 Oph	Kwee, *B.A.N.* **14**, 131, 1958.
V 566 Oph	Kwee, *B.A.N.* **14**, 131, 1958; Binnendijk, *Astr. J.* **64**, 65, 1959; Purgathofer, *Mitt. Univ. Sternw. Wien* **10**, 119, 1959; Worley (Lick Obs.).
V 839 Oph	Binnendijk, *Astr. J.* **65**, 79, 1960.
ER Ori	Kwee, *B.A.N.* **14**, 131, 1958.
U Peg	Kwee, *B.A.N.* **14**, 131, 1958; Binnendijk, *Astr. J.* **65**, 88, 1960.
AW Peg	Fresa (Capodimonte).
β Per	Herczeg, *Z.Ap.* **48**, 298, 1959; ——, *Veröff. Sternw. Bonn* 54, 1959; Plavec (Ondrejov); Chou (Flower and Cook Obs., three colours); Reuning (Flower and Cook Obs., infra-red).
SZ Psc	Bakos and Heard, *Astr. J.* **63**, 302, 1958.
UU Psc	Magalashvili and Kumsishvili, *Bull. Abastumani Astrophys. Obs.* 22, 1958.
V Pup	Somerville (Stromlo).
RZ Pyx	Kinman, *Observatory* **80**, 148, 1960; ——, *Mon. Not. astr. Soc. S. Afr.* **19**, 62, 1960.
V 505 Sgr	Somerville (Stromlo).
V 499 Sco	Cillié and Lindsay, *Armagh Obs. Contr.* 22, 1957.
RT Scl	Cillié and Lindsay, *M.N.R.A.S.* **118**, 585, 1958; ——, *Armagh Obs. Contr.* 25, 1958.
RS Sct	Kwee, *B.A.N.* **14**, 131, 1958.
RW Tau	Kordylewski and Szafraniec, *Acta astr. Cracoviae* **7**, 177, 1957; Grant, *Ap. J.* **129**, 62, 1959.
λ Tau	Grant, *Ap. J.* **129**, 78, 1959.
V Tuc	F. B. Wood, *Astr. J.* **64**, 57, 1959; Hogg and Somerville (Stromlo).
AN Tuc	Somerville (Stromlo).
W UMa	Chou, *Astr. J.* **64**, 471, 1959.
AL Vel	F. B. Wood (Flower and Cook Obs., two colours).
AG Vir	Kwee, *B.A.N.* **14**, 131, 1958; Szczepanowska, *Acta astr. Cracoviae* **8**, 36, 1958.
AH Vir	Kitamura, Tanabe and Nakamura, *Publ. astr. Soc. Japan* **9**, 121, 1957; Kwee, *B.A.N.* **14**, 131, 1958; Binnendijk, *Astr. J.* **65**, 358, 1960.
BF Vir	Kwee, *B.A.N.* **14**, 131, 1958.
BH Vir	Kitamura, Nakamura and Takahashi, *Publ. astr. Soc. Japan* **9**, 191, 1957.
Z Vul	Kordylewski and Szafraniec, *Acta astr. Cracoviae* **7**, 177, 1957; Broglia (Merate); Wesselink (Radcliffe, two colours).
ER Vul	Abrami and Cester (Trieste).
B.D. $+35°$ 4492	Cester (Trieste).
B.D. $+35°$ 4496	Deinzer u. Geyer, *Z. Ap.* **47**, 211, 1959.
B.D. $+74°$ 877	Archer, *J. Brit. astr. Ass.* **69**, 38, 1959.
B.D. $+75°$ 791	Abrami (Trieste).
H.D. 16157	Evans, *M.N.R.A.S.* **119**, 526, 1959.
H.D. 208392	Lynds, *Ap. J.* **130**, 594, 1959; ——, *Ap. J.* **130**, 603, 1959.
H.D. 224151	Lynds, *Ap. J.* **130**, 599, 1959.

NEW SPECTOGRAPHIC DATA

In Table 2 are listed the eclipsing systems for which spectrographic observations have been published since the last report, or are now being carried on. There has been a considerable increase in the number of spectroscopists observing eclipsing binaries. The number of observers listed in Table 2, together with additional names in the co-ordinated programmes, amounts to 60, as compared with 40 observers in the previous report. There still remains a great deal to be done. It was decided at the Moscow meeting (*Trans. IAU* **10**, 637) that Commission 42 should undertake the preparation of a list of eclipsing binaries most in need of spectroscopic observation. A. H. Batten drew up (*a*) an annotated list of nineteen eclipsing

Table 2. New spectrographic observations

Star	References
AN And	Cester, *Mem. Soc. astr. Ital.* **30,** 213, 1960.
ϵ Aur	Wright and Kushwaha, *P.A.S.P.* **69,** 402, 1957; ——, *Mém. Soc. Sci. Liège* (4) **20,** 421, 1958; Hack, *P.A.S.P.* **69,** 389, 1957; ——, *Ap. J.* **129,** 291, 1959; Struve, Pillans and Zebergs, *Ap. J.* **128,** 287, 1958; Wright, *Astr. J.* **63,** 312, 1958; Fracassini and Hack, *Mem. Soc. astr. Ital.* **29,** 101, 1958; McKellar, Wright and Lee (Victoria, high dispersion).
ζ Aur	McKellar and Butkov, *Publ. Dom. astrophys. Obs.* **10,** 341, 1956; Groth, *Z. Ap.* **43,** 185, 1957; Kawabata, *Publ. astr. Soc. Japan* **9,** 72, 1957; Lee and Wright, *Publ. Dom. astrophys. Obs.* **11,** no. 17.
SZ Cam	Petrie (Victoria).
UW CMa	Struve, Sahade, Zebergs and Lynds, *P.A.S.P.* **70,** 267, 1958; Struve, Sahade, Huang and Zebergs, *Ap. J.* **128,** 328, 1958; Sahade, *P.A.S.P.* **71,** 151, 1959.
RS CVn	Popper, *Astr. J.* **64,** 344, 1959.
δ Cap	Batten (Victoria).
GL Car	Wesselink (Pretoria).
AO Cas	Struve and Sahade, *P.A.S.P.* **70,** 111, 1958; Abhyankar, *Ap. J. Suppl.* **4,** 187, 1959; Mannino, *Mem. Soc. astr. Ital.* **30,** 19, 1959.
AR Cas	Batten (Victoria).
DO Cas	Mannino, *Mem. Soc. astr. Ital.* **29,** 433, 1958.
V 346 Cen	Wesselink (Pretoria).
VV Cep	McKellar, Wright and Francis, *P.A.S.P.* **69,** 442, 1957; Keenan and Wright, *P.A.S.P.* **69,** 457, 1957; McKellar, Wright and Lee (Victoria, high dispersion).
VW Cep	Odgers (Victoria).
CQ Cep	Sahade, *Mem. Soc. Sci. Liège* (4) **20,** 46, 1958.
W Cru	Woolf (Pretoria).
AI Cru	Wesselink (Pretoria).
Y Cyg	Struve, Sahade and Zebergs, *Ap. J.* **129,** 59, 1959; Huffer and Karle, *Ap. J.* **129,** 237, 1959.
V 444 Cyg	Sahade, *Mém. Soc. Sci. Liège* (4) **20,** 46, 1958.
V 448 Cyg	Struve, *P.A.S.P.* **70,** 608, 1958.
V 477 Cyg	Pearce, *Publ. Dom. astrophys. Obs.* **10,** 447, 1957.
31 Cyg	McKellar and Petrie, *Publ. Dom. astrophys. Obs.* **11,** 1, 1958; McKellar, Aller, Odgers and Richardson ,, ,, **11,** 35, 1959; Wright and Lee, ,, ,, ,, **11,** 59, 1959; Wright, ,, ,, ,, **11,** 77, 1959.
32 Cyg	Wright and McDonald, *P.A.S.P.* **71,** 506, 1959.
S Equ	Petrie (Victoria) and Plavec (Ondrejov).
YY Gem	Struve and Zebergs, *Ap. J.* **130,** 783, 1959.
RX Her	Popper, *Ap. J.* **129,** 659, 1959.
DQ Her	Greenstein and Kraft, *Ap. J.* **130,** 99, 1959; Kraft, *Ap. J.* **130,** 110, 1959.
TX Leo	Chamberlin and McNamara, *P.A.S.P.* **69,** 462, 1957.
XY Leo	Struve and Zebergs, *Ap. J.* **130,** 137, 1959.
β Lyr	Saidow, *Trans. Acad. Sci. Tadjik S.S.R.* **66,** 6, 1957; Houziaux, *P.A.S.P.* **70,** 209, 1958; ——, *Z. Ap.* **45,** 264, 1958; Struve and Sahade, *P.A.S.P.* **70.** 313, 1958; Struve, *P.A.S.P.* **70,** 585, 1958; Sahade, *Astr. J.* **63,** 52, 1958; Sahade, Huang, Struve and Zebergs, *Trans. Amer. phil. Soc.* **49,** pt. 1, 1959; Struve and Zebergs, *Ap. J.* **130,** 817, 1959; Struve, Svolopoulos and Zebergs, *Ap. J.* **131,** 111, 1960.
U Oph	Abrami, *Mem. Soc. astr. Ital.* **29,** 381, 1958.
V 502 Oph	Struve and Zebergs, *Ap. J.* **130,** 789, 1959.
V 566 Oph	Heard (Toronto).

Star	References
AR Pav	Thackeray, *M.N.R.A.S.* **119,** 629, 1959.
β Per	Arakeljan, *Bull. Burakan Obs.* 21, 1957; Sahade and Wallerstein, *P.A.S.P.* **70,** 207, 1958; Ebbighausen, *Ap. J.* **128,** 598, 1958; Ebbighausen and Struve, *P.A.S.P.* **71,** 39, 1959.
ϵ Per	Petrie (Victoria).
ζ Phe	Hagemann, *M.N.R.A.S.* **119,** 142, 1959.
SZ Psc	Bakos and Heard, *Astr. J.* **63,** 302, 1958.
UU Psc	Cester, *Mem. Soc. astr. Ital.* **30,** 229, 1959.
V Pup	Frieboes and Sahade (La Plata).
VV Pup	Herbig, *Astr. J.* **64,** 128, 1959; ——, *Ap. J.* **132,** 76, 1960.
RZ Pyx	Kinman, *Observatory* **80,** 148, 1960; ——, *Mon. Not. astr. Soc. S. Afr.* **19,** 62, 1960.
U Sge	McNamara, *P.A.S.P.* **71,** 241, 1959.
V 523 Sgr	Wesselink (Pretoria).
V 526 Sgr	Wesselink (Pretoria).
RZ Sct	McNamara, *P.A.S.P.* **69,** 574, 1957; McNamara and Hansen, *Ap. J.* **128,** 77, 1958; Hansen and McNamara, *Ap. J.* **130,** 806, 1959; ——, *P.A.S.P.* **72,** 36, 1960.
W Ser	C. R. Lynds, *P.A.S.P.* **69,** 392, 1957; Beer, *Mém. Soc. Sci. Liège* (4) **20,** 387, 1958; Sahade and Struve, *Mém. Soc. Sci. Liège* (4) **20,** 394, 1958; Hack, *Mém. Soc. Sci. Liège* (4) **20,** 397, 1958; ——, *Mém. Soc. astr. Ital.* **29,** 41, 1958.
RW Tau	Petrie (Victoria) and Plavec (Ondrejov).
AL Vel	Wesselink (Pretoria).
γ Vel	S. Gaposchkin, *Astr. J.* **64,** 127, 1959.
α Vir	Struve, Sahade, Huang and Zebergs, *Ap. J.* **128,** 310, 1958.
H.D. 16157	Evans, *M.N.R.A.S.* **119,** 526, 1959.
H.D. 47129	Struve, Sahade and Huang, *Ap. J.* **127,** 148, 1959; Abhyankar, *Ap. J. Suppl.* **4,** 157, 1959.
Boss 5070	Batten (Victoria).

systems, reasonably well observed photometrically but needing radial velocity curves, together with (*b*) a list of sixteen W Ursae Majoris systems, which are probably too faint for velocity curves to be obtained, but which lack spectral classification. Through the kindness of Z. Kopal these lists were re-duplicated in the Astronomy Department of the University of Manchester and distributed (in March 1959) to members of Commissions 30 and 42 and Sub-Commission 30*b*. A. H. Batten has now prepared a supplement to list (*a*), which R. M. Petrie has kindly re-duplicated and distributed from the Dominion Astrophysical Observatory.

CO-ORDINATION OF PHOTOMETRIC AND SPECTROGRAPHIC OBSERVATIONS

At the Moscow meeting the Commission approved a programme of co-ordinated world-wide observations of ζ Aur, AR Cas, VW Cep and β Lyr. An appeal to participate in these programmes, signed by the President and Secretary of the Commission, was sent in May 1959 to members of Commissions 30 and 42 and Sub-Commission 30*b*, as well as to a number of other astronomers. The results so far obtained are summarized in the following report. Full reports will be published in due course by the respective co-ordinators.

ζ Aurigae. K. Gyldenkerne, the co-ordinator for this programme, proposed that, as the 1961 minimum would be unsuitable for observations, the campaign be organized for the 1963–4 eclipse, particularly from 1963 December 3 to 1964 January 11.

AR Cassiopiae. C. M. Huffer, who agreed to act as co-ordinator, selected the period from 1959 October 10 to December 17 for photometric and spectrographic observations. He reports that the international co-operation was not satisfactory. Bad weather prevented observations in many places. Photo-electric observations were made at Lick Observatory (Mrs Kron).

VW Cephei. The co-ordinator of the programme, K. K. Kwee, issued five circulars to prospective observers between May 1959 and June 1960. There follows a summary of his report.

Recent observations of VW Cep at Leiden Observatory showed that, superimposed on a slow variation of the period, a smaller and more rapid fluctuation exists, with a range of about $0^{d}{\cdot}004$ and a period of about two years. This smaller fluctuation is correlated with, and probably caused by, distortions in the light-curve. The principal aim of the campaign was to study these variations in the light-curve from cycle to cycle, and to find out if they are accompanied by spectral changes. Four observing periods were chosen, each of six days, between 1959 September 14 and November 7. The photometric part of the campaign was very successful. Twenty-one observers in twelve observatories made a total of 8721 photo-electric observations. Observations in two other observatories, Kazan and Sidmouth, were prevented by bad weather. Only large telescopes could take part in the spectrographic programme, which, on account of bad weather, was not so successful as the photometric programme.

The photometric observations will be published shortly in the *Leiden Annals*, except those made at Budapest and Stockholm, which are being published by these observatories. The material will be analysed with the aid of an electronic computer at Flower and Cook Observatory by Jurkevich, working under the supervision of Merrill, Wood and Binnendijk. The following photo-electric observers participated:

Abastumani: Magalashvili and Kumsishvili (2 colours)
Brorfelde: Gyldenkerne, Jaeger and Johansen
Budapest: Detre, Balázs-Detre, Kanyó and Gifferth (4 colours)
Graz: Rakosch (2 colours)
Hoher List: Schmidt and Herczeg (2 colours)
Leiden: Kwee and van Agt (5 colours)
Potsdam: Schneller (2 colours)
Stockholm: Larsson-Leander (2 colours)
Tokyo: Kitamura (2 colours)
Topeka: Alexander (2 colours)
Trieste: Martin and Cester (2 colours)
Washington (Georgetown): Coyne (3 colours)

Spectroscopic observations were made by:

Mount Wilson and Palomar: Deutsch and Bonsack
Richmond Hill: Morris

β Lyrae. The co-ordinator for this programme was G. Larsson-Leander. The following comments are taken from his letters and from the five circulars issued by him to observers. The programme was proposed by Struve. Secondary variations have been noted in the light-curve. Two successive primary minima, observed photo-electrically at Lick by D. B. Wood, showed considerable differences, which Struve found clearly correlated with differences in the intensities of the spectral lines produced by the outer shell of the star. The campaign was planned for the interval 1959 August 8 to September 11 so as to cover three successive primary minima. The photo-electric coverage was very good indeed. The following photo-electric observers participated:

Abastumani: Magalashvili and Kumsishvili (2 colours)
Brorfelde: Gyldenkerne (2 colours)
Budapest: Balázs-Detre (4 colours)
Capodimonte: Fresa
Cracow: Szafraniec (2 colours)
Flower and Cook: Binnendijk (3 colours); Bookmyer (2 colours)
Hoher List: Herczeg (3 colours)
Leiden: Kwee and van Agt (4 colours)
Lick: Mrs Kron (2 colours)
Nanking: Chang
Pic-du-Midi: Bouigue, Pedoussant and Rouchette (5 colours)
Sidmouth: Archer (2 colours)
Stockholm: Larsson-Leander (2 colours)

High-dispersion spectrograms were obtained at McDonald Observatory by Abt and at Victoria by K. O. Wright and McKellar. Abt will deal with the spectrographic material. The photo-electric observations will be discussed by Larsson-Leander.

32 *Cygni.* K. Gyldenkerne organized observations of 32 Cyg during the eclipse of April 1959. The star was not favourably placed for observation at that time and only a few observatories could participate. Photo-electric and spectrographic observers are listed in Tables 1 and 2.

Future co-operative programmes on these lines will be discussed at the Berkeley meeting.

TIMES OF MINIMA AND PERIOD VARIATIONS

Previous reports of this Commission stressed the importance of accurate and regular determinations of the times of minima of eclipsing binaries. It is gratifying to note that these recommendations have borne fruit. Extensive lists of minima have been published by the Cracow (**8-12**) and Warsaw (**13**) observers, by a group of German astronomers (**14**), as well as by the authors listed in Table 3. Much material for the determination of earlier epochs of minima will be found in 'The Cracow Observations of Variable Stars 1920–50', of which the first part (**15**), listing visual observations of 429 stars (mostly eclipsing variables), was issued recently.

In accordance with a resolution of Commission 42 (*Trans. IAU* **10**, 636) Kordylewski has prepared for print 'Eclipsing Variable Circulars', containing the observed times of minima published since 1957, together with unpublished data received by the Centre for Eclipsing Variables at Cracow. The circulars will be issued a few times a year. The material has been supplied by fifty observers. Kordylewski invited amateur astronomers in Poland and Czechoslovakia to partake in the programme, with good results. It is hoped that amateur astronomers elsewhere will follow suit. The Centre for Eclipsing Variables at Cracow supplies charts and comparison stars to observers. Szafraniec has prepared charts for 146 southern eclipsing binaries, in the hope that amateur astronomers in the southern hemisphere will also join in this useful work.

In cases when it is necessary to determine epochs of minima more accurately than can be done by graphical methods, the method described by Kwee and van Woerden (**16**) is to be recommended. The same problem has been treated also by Albo (**17**).

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Investigations of period variations made since the last report are listed in Table 3 (systems where no variation has been found are not included in the table). Whitney (**18**) studied the periods of seventy eclipsing variables observed by him, 36 of which, listed in Table 3, he found

Table 3. Discussions of periods of eclipsing binary systems

Star	References
TT And	Whitney, *Astr. J.* **64**, 258, 1959.
UU And	Whitney, *Astr. J.* **64**, 258, 1959.
WZ And	Whitney, *Astr. J.* **64**, 258, 1959.
AB And	Binnendijk, *Astr. J.* **64**, 69, 1959.
BX And	Chou, *Astr. J.* **64**, 469, 1959.
SU Aqr	Whitney, *Astr. J.* **64**, 258, 1959.
XZ Aql	Erleksova, *Per. Zvezdy* **12**, 293, 1959; Whitney, *Astr. J.* **64**, 258, 1959.
RZ Aur	Whitney, *Astr. J.* **64**, 248, 1959.
WW Aur	Chou, *Astr. J.* **64**, 471, 1959; Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
SU Boo	Broglia, *Mem. Soc. astr. Ital.* **31**, 107, 1960.
44 i Boo	Kwee, *B.A.N.*, **14**, 131, 1958.
RY Cnc	Whitney, *Astr. J.* **64**, 258, 1959.
TU Cnc	Whitney, *Astr. J.* **64**, 258, 1959.
TY Cnc	Whitney, *Astr. J.* **64**, 258, 1959.
YY Cnc	Kuklin, *Astr. Circ. U.S.S.R.* 202, 1959.
R CMa	Koch, *Astr. J.* **65**, 326, 1960.
RS CVn	Plavec and Smetanova, *Bull. astr. Insts. Csl.* **10**, 192, 1959.
GL Car	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
RZ Cas	Wroblewski, *Acta astr. Cracoviae* **9**, 104, 1959.
TV Cas	Chou, *Astr. J.* **64**, 468, 1959.
AO Cas	Koch, *Astr. J.* **65**, 127, 1960.
CW Cas	Broglia, *Contr. Oss. astr. Merate* 113, 1957.
EN Cas	Whitney, *Astr. J.* **64**, 258, 1959.
VW Cep	Kwee, *B.A.N.* **14**, 131, 1958; Szczepanowska, *Acta astr. Cracoviae* **9**, 38, 1959.
SS Cet	Tsesevich, *Astr. Circ. U.S.S.R.* 195, 1958; Whitney, *Astr. J.* **64**, 258, 1959.
Y Cyg	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
SW Cyg	Whitney, *Astr. J.* **64**, 258, 1959.
UW Cyg	Whitney, *Astr. J.* **64**, 258, 1959.
CV Cyg	Belyakova and Grigorevsky, *Astr. Circ. U.S.S.R.* 207, 1959; Whitney, *Astr. J.* **64**, 258, 1959.
GM Cyg	Whitney, *Astr. J.* **64**, 258, 1959.
GO Cyg	Kwee, *B.A.N.* **14**, 131, 1958.
MR Cyg	Whitney, *Astr. J.* **64**, 258, 1959; Istchenko, *Per. Zvezdy* **12**, 117, 1959.
V 346 Cyg	Whitney, *Astr. J.* **64**, 258, 1959.
V 382 Cyg	Whitney, *Astr. J.* **64**, 258, 1959.
W Del	Plavec, *Bull. astr. Insts. Csl* **10**, 185, 1959.
TT Del	Whitney, *Astr. J.* **64**, 258, 1959.
RZ Dra	Whitney, *Astr. J.* **64**, 258, 1959.
SX Dra	Whitney, *Astr. J.* **64**, 258, 1959.
YY Eri	Kwee, *B.A.N.* **14**, 131, 1958.
YY Gem	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
AY Gem	Whitney, *Astr. J.* **64**, 258, 1959.
TX Her	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Cs.* **11**, 180, 1960.
AK Her	Kwee, *B.A.N.* **14**, 131, 1958; Schmidt u. Herczeg, *Z. Ap.* **47**, 106, 1959.
BO Her	Whitney, *Astr. J.* **64**, 258, 1959.
DQ Her	Herczeg, *Mem. Soc. astr. Ital.* **29**, 145, 1958; Rosino, *Mem. Soc. astr. Ital.* **29**, 233, 1958.

Star	References
SW Lac	Kwee, *B.A.N.* **14**, 131, 1958.
TW Lac	Whitney, *Astr. J.* **64**, 258, 1959.
UW Lac	Whitney, *Astr. J.* **64**, 258, 1959.
RW Leo	Whitney, *Astr. J.* **64**, 258, 1959.
XY Leo	Koch, *Astr. J.* **65**, 374, 1960.
UX Mon	Whitney, *Astr. J.* **64**, 258, 1959.
U Oph	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
V 451 Oph	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
V 502 Oph	Kwee, *B.A.N.* **14**, 131, 1958.
ER Ori	Kwee, *B.A.N.* **14**, 131, 1958.
FL Ori	Whitney, *Astr. J.* **64**, 258, 1959.
U Peg	Kwee, *B.A.N.* **14**, 131, 1958; Binnendijk, *Astr. J.* **65**, 88, 1960.
AQ Peg	Whitney, *Astr. J.* **64**, 258, 1959.
WY Per	Whitney, *Astr. J.* **64**, 258, 1959.
XZ Per	Whitney, *Astr. J.* **64**, 258, 1959.
β Per	Gadomski, *Acta astr. Cracoviae* **8**, 171, 1958; Kopal, Plavec and Reilly, *Jodrell Bank Ann.* **1**, 374, 1960.
Y Psc	Whitney, *Astr. J.* **64**, 258, 1959.
RS Sgr	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
XZ Sgr	Lange, *Astr. Circ. U.S.S.R.* 199, 1959.
BN Sgr	Whitney, *Astr. J.* **64**, 258, 1959.
BQ Sgr	Whitney, *Astr. J.* **64**, 258, 1959.
V 467 Sco	Whitney, *Astr. J.* **64**, 258, 1959.
RS Sct	Kwee, *B.A.N.* **14**, 131, 1958; Whitney, *Astr. J.* **64**, 258, 1959.
W Ser	Fresa, *Mém. Soc. Sci. Liège* (4) **20**, 384, 1958.
RW Tau	Grant, *Ap. J.* **129**, 62, 1959; Abt and Van Biesbroeck, *P.A.S.P.* **71**, 345, 1959; Plavec, *Publ. astr. Insts. Csl.* 46, 1960.
W UMa	Chou, *Astr. J.* **64**, 471, 1959.
TX UMa	Plavec, *Bull. astr. Insts. Csl.* **11**, 148, 1960.
AG Vir	Kwee, *B.A.N.* **14**, 131, 1958.
AH Vir	Kwee, *B.A.N.* **14**, 131, 1958; Binnendijk, *Astr. J.* **65**, 358, 1960.
AT Vul	Whitney, *Astr. J.* **64**, 258, 1959.
BU Vul	Whitney, *Astr. J.* **64**, 258, 1959.
DR Vul	Erleksova, *Per. Zvezdy* **12**, 298, 1959.

to vary. Abt and van Biesbroeck (**19**) consider that the variation of period of RW Tau is consistent with motion about a third body, which is not, however, the $12^{m}\cdot5$ visual companion found by Joy. Plavec (**20**), on the other hand, concluded that motion about a third body, or apsidal motion, can be excluded and that we have here a real change in the true orbital period. Some problems connected with changes of the period of close binaries are discussed by Krat (**21**). Prikhodko (**21a**) investigated the periods of 19 eclipsing variables, but found no indications of variation in the periods. The periods of RZ and TW Dra, AK Her, AM Leo, V 451 Oph, W. UMa and BF Vir are being studied by a group of observers at Flower and Cook Observatory. Purgathofer and Widorn at Vienna are observing photo-electrically some two dozen short-period eclipsing binaries for changes of period.

Plavec has initiated at Ondrejov a study of the period variations of eclipsing binaries, commencing with the detached systems (**22**). For only 12 of the 28 detached systems listed by Kopal and Shapley (**23**) was there enough material for an investigation. Four of these showed no sign of varying period; the remaining eight are listed in Table 3. Kopal and Palmer are carrying out a parallel study at Manchester.

Period changes in eclipsing binaries may be caused by rotation of the line of apsides, or by motion of the eclipsing pair about a third body, or by physical changes in the components of close binaries, such as transfer of mass from one component to the other or loss of mass from the system. Before concluding that variations of period in any system are caused by physical changes in the system, one must first eliminate the effects due to apsidal motion or to the presence of a third body, and, at Kopal's suggestion, Plavec has been investigating this point. The most thorough analytical treatment yet published of the dynamics of close binary systems is that given by Kopal in his recent book (**2**), where he discusses the effects of tidal distortion of the components and of internal structure. For the variation of period he finds nine new periodic terms due to precession and nutation and their combination with apsidal motion. In order to see how far it is possible to detect these new terms in practice, Plavec (**24**) has studied twelve eclipsing systems, five detached, five semi-detached and two contact systems, on the basis of the theoretical stellar models of Kushwaha and Schwarzschild. He comes to the conclusion that the amplitudes of these periodic terms are very small and in general undetectable.

Kwee (**25**) made photo-electric observations of sixteen eclipsing binaries with periods $<0^{d}\cdot75$, for a study of their periods. The periods of OO Aql, DO Cas, V 566 Oph and BF Vir he found to be sensibly constant; the other twelve systems are given in Table 3. He finds two kinds of period variations: small and rapid fluctuations, probably due to distortions of the light-curve, and variations of longer period. Most of the systems studied are probably near a state of dynamical instability, and processes due to this instability, such as loss of mass from the system, or mass transfer between the components, have been invoked by many authors to explain changes in period. Kwee examines in particular the case of a transfer of mass between the components. For the observed period variations dP/P, of the order of 10^{-5}, mass transfers dm/m of the order of 10^{-5} or 10^{-6} would be involved. His calculations show further that the changes in dimensions of the components would be of the same order as the changes in mass. While such changes are not impossible, Kwee points out certain difficulties in assuming that the observed variations in period are caused by mass transfer. One serious objection is the fact that it does not explain period changes in semi-detached systems, in which only one component has reached the limit of stability, whereas these systems show period variations similar in character to those of contact binary systems.

Schneller (**26**) gives briefly the results of an investigation into the proportion of varying periods among the detached, semi-detached and contact systems of Kopal's classification. He remarks that, in most cases of period variation, the cause seems to be some brief, catastrophic process. Herczeg (**27**) summarizes the possible causes of period variation. He emphasizes the great importance of accurate determinations of epochs of minima, and discusses various factors that cause inaccuracy. Prikhodko (**28**) examined the statistical dependences of the change of period on the period itself, on the semi-axis of the relative orbit, and on the ratio of the densities of the components. Kordylewski (**29**) compared the variations in period of eclipsing binaries with those of RR Lyrae variables, plotting in each case the deviations from a constant period against the Julian Day, not against the epoch number, as is usually done. He finds that various typical period variations of eclipsing binaries show close similarities to those of various RR Lyrae variables.

The analysis of the variation of period due to the motion of the eclipsing pair about a third component was dealt with many years ago by Woltjer (**30**). Tables computed recently by Irwin (**31**) will greatly facilitate the solution of this problem.

APSIDAL MOTION

In Table 4 are listed the investigations of apsidal motion that have been published in the last three years. From the apsidal motion in four systems with sub-giant components Plavec (**32**) has derived the density distribution in the sub-giants and finds a polytropic index of about 3·6 for the secondary components of *Algol*, W Del and TX UMa, and 3·1 for that of RS CVn. Kopal, Plavec and Reilly find that the 32-year period in the *Algol* system can be explained in

Table 4. Investigations of apsidal motion

Star	References
RS CVn	Plavec and Smetanova, *Bull. astr. Insts. Csl.* **10**, 192, 1959; Plavec, *Bull. astr. Insts. Csl.* **11**, 154, 1960.
GL Car	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
Y Cyg	Struve, Sahade, and Zebergs, *Ap. J.* **129**, 59, 1959; Huffer and Karle, *Ap. J.* **129**, 237, 1959; Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
V 477 Cyg	Pearce, *Publ. Dom. astrophys. Obs.* **10**, 447, 1957.
W Del	Plavec, *Bull astr. Insts. Csl.* **10**, 185, 1959; **11**, 148, 1960.
YY Gem	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
V 451 Oph	Plavec, Pekny and Smetanova, *Bull. astr. Insts. Csl.* **11**, 180, 1960.
β Per	Plavec, *Bull. astr. Insts. Csl.* **11**, 148, 1960; Kopal, Plavec and Reilly. *Jodrell Bank Ann.* **1**, 374, 1960.
TX UMa	Plavec, *Bull. astr. Insts. Csl.* **11**, 148, 1960.
α Vir	Struve. Sahade, Huang and Zebergs, *Ap. J.* **128**, 310, 1958.
DR Vul	Erleksova, *Per Zvezdy* **12**, 198, 1958.

terms of apsidal motion (**94**). Plavec (**33**) has published a table which facilitates the computation of the factors depending on the eccentricity of the orbit in Sterne's and Kopal's formulae for the period of apsidal motion.

Levi-Civita's results for the relativistic advance of periastron in a binary system (**34**) have been applied by Rudkjøbing (**35**) to the case of DI Her. He finds that the relativistic term accounts for 60% of the predicted apsidal motion, calculated on the basis of various assumptions as to the dimensions and internal structure of the components. No indication of apsidal motion has in fact been observed as yet in this system.

DETERMINATION OF PHOTOMETRIC ORBITS

In Table 5 are listed those systems for which photometric orbits have been published since the last report. Binnendijk (private communication) considers that four W Ursae Majoris systems have reliable orbital elements, because the eclipses are complete: AK Her, AM Leo and AH Vir (all in Table 5) and FG Hya (Smith, unpublished Harvard dissertation).

Table 5. New solutions of photometric curves

Star	References
o And	Schmidt, *Z. Ap.* **48**, 249, 1959.
SY Boo	Broglia, *Mem. Soc. astr. Ital.* **31**, 107, 1960.
R CMa	Koch, *Astr. J.* **65**, 326, 1960.
SX Cas	Günther, *Astr. Nach.* **285**, 97, 105, 1959.
YZ Cas	Semenova, *Pulkovo Bull.* 159, 1958.
U Cep	Bolokadze, *Per. Zvezdy* **11**, 375, 1958.
VV Cep	Fredrick, *Astr. J.* (in press).
XX Cep	Lavrov, *Per. Zvezdy*, **12**, 21, 1959.
IW Cet	Archer, *Ap. J.* **130**, 774, 1959.
TZ CrA	F. B. Wood, *Astr. J.* **65**, 23, 1960.

Star	References
U CrB	D. B. Wood, *Ap. J.* **128,** 595, 1958.
Y Cyg	Magalashvili and Kumsishvili, *Bull. Abastumani Astrophys. Obs.* 24, 1959.
V 382 Cyg	Albo, *Per Zvezdy* **12,** 240, 1958.
DM Del	Schneller, *Astr. Nach.* **285,** 265, 1960.
TW Dra	Bolokadze, *Per Zvezdy* **11,** 375, 1958.
AI Dra	Cester, *Mem. Soc. astr. Ital.* **30,** 287, 1960.
AS Eri	Koch, *Astr. J.* **65,** 139, 1960.
AK Her	Binnendijk (Flower and Cook Obs.)
DQ Her	Herczeg, *Mem. Soc. astr. Ital.* **29,** 145, 1958.
CM Lac	Alexander, *Astr. J.* **63,** 106, 1958.
Y Leo	Johnson, *Ap. J.* **131,** 127, 1960.
XY Leo	Koch, *Astr. J.* **65,** 374, 1960.
AM Leo	Abrami, *Mem. Soc. astr. Ital.* **30,** 303, 1960.
RR Lyn	Magalashvili and Kumsishvili, *Bull. Abastumani Astrophys. Obs.* 24, 1959.
RW Mon	Batten, *Ann. Ap.* **20,** 103, 1957.
U Peg	Binnendijk, *Astr. J.* **65,** 88, 1960.
β Per	Herczeg, *Veröff. Sternw. Bonn.* 54, 1959; Hosokawa, *Publ astr. Soc. Japan* **10,** 120, 1958.
RZ Pyx	Kinman, *Mon. Not. astr. Soc. S. Afr.* **19,** 62, 1960.
λ Tau	Grant, *Ap. J.* **129,** 78, 1959.
RW Tau	Grant, *A. J.* **129,** 62, 1959.
γ Vel	Gaposchkin, *Astr. J.* **64,** 1959.
AH Vir	Kitamura, Tanabe and Nakamura, *Publ. astr. Soc. Japan* **9,** 121, 1957; Kitamura and Takahashi, *Tokyo astr. Bull.* 123, 1959; Binnendijk, *Astr. J.* **65,** 358, 1960.
BH Vir	Kitamura, Nakamura and Takahashi, *Publ. astr. Soc. Japan* **9,** 191, 1957.
5·1938 Tri	Protitch, *Per Zvezdy* **11,** 312, 1958.

Kopal's method of analysing light curves for orbit determination is treated fully in his book *Close Binary Systems* (**2**). Irwin (**36**) is preparing a general treatment of photometric orbit determination by way of introduction to the subject, and has also computed tables for the coefficient of darkening $x=0{\cdot}5$. J. E. Merrill's work on the illustrative examples for the use of his tables is well advanced. He has worked out a rather more direct approach to the intermediate solution, while for preliminary solutions he has just developed a much-simplified procedure, applicable to both partial and total eclipses, utilizing new tables of $\sqrt{^6\chi^{oc}}$ and $\sqrt{^6\chi^{tr}}$. Schneller (**37**) has published recently a valuable collection of tables to facilitate the analysis of light curves by various methods. Included are tables of the functions $q\ (k,a,x) = (\bar{\delta}_3{}^2-\bar{\delta}_2{}^2)/(\bar{\delta}_1{}^2-\bar{\delta}_2{}^2)$, $\delta=\delta(k,a,x)$, $\sin\phi$, $\cos\phi$, $\sin^2\phi$, $\cos^2\phi$, and a table, for the rectification of the phase by Merrill's method, of $\sin^2\theta=(1-z\cos^2\theta)\sin^2\Theta$.

Much attention is being devoted to the observation of atmospheric eclipses. The theory of the absorption of light in extended atmospheres has been discussed by Linnell (**38**), who is using an IBM 704 electronic computer to prepare tables of the fractional light losses in atmospheric eclipses.

In a number of observatories studies are being made of the use of electronic computers for the analysis of light-curves of eclipsing binaries. In the previous report (*Trans. IAU* **10,** 629) mention was made of Wellmann's use of the FERUT computer at Toronto for this purpose. Since then he has worked out a similar programme for the IBM computer at Hamburg (**39**). No details have been published as yet, but Herczeg has used Wellmann's method in his study of *Algol* (**40**). At Washburn Observatory Huffer and his staff have completed the programming for the IBM 650 computer, using Kopal's method for the analysis of the light curves. Later on, the new CDC 1604, which is being acquired by the University of Wisconsin, will be used.

Wood and Binnendijk and others of the staff of Flower and Cook Observatory are also active in this field.

Kopal (41) has been much concerned with the special problems presented by the light-curves of close binary systems. He writes as follows:

'While writing the subject matter of Chapter VII of my book I became conscious with increasing acuteness of the fact that while the methods available at present are probably as good as any for interpretation of light-curves of well separated systems, they are probably fundamentally unsuitable for the light-changes of close binaries where the variation of light arising from the eclipses and the ellipticity of figure are inseparably interlocked. In giving this problem considerable thought for a long time I have now come to the conclusion that the royal road for dealing with such systems will not be in the time domain (*i.e.* the interpretation of the light-curve represents plots of light versus time), but rather in the frequency domain (*i.e.*, the Fourier transforms of the observed light changes) in which the operations of 'rectification' and 'solution for the elements' do not become consecutive (as in the time domain), but simultaneous.'

Hosokawa (42) compared the theoretical reflection coefficient (computed on the assumption of a non-grey atmosphere) with the observed coefficients for 30 eclipsing binaries. For systems with at least one B-type component the observed coefficients are appreciably smaller than the calculated ones. For these systems Hosokawa found deviations from theory also in his study of photometric ellipticity (*Trans. IAU* **10**, 629). He has also studied the reflection effect in *Algol* (43). Kitamura (44) has derived a formula for any phase function of the reflection effect and compares the various phase-laws. Batten (45) obtained a phase-law for the effect of reflection on the radial velocity of the component of a binary, and from this law derived the correction to be made to the observed masses. He finds that the correction amounts to about 10% of the mass of the heavier component, except for very close systems, where the correction may be much larger.

Observations of YZ Cas, β Lyr and β Per, with a Maksutov camera and objective prism, were made at Pulkovo Observatory by Semenova (46) for a study of the limb-darkening in different wave-lengths (YZ Cas was observed in five wave-lengths). The Wyse-Tsesevich and Krat methods for determining the coefficient of darkening were found to give reliable results. Serkowski (Warsaw Observatory), seeking a more accurate method of determining the differential limb-darkening from two-colour photometric observations, writes:

'We must consider all the first-order effects upon which the colour index of an eclipsing binary depends during the eclipse. We may write the system of linear equations with following unknowns: (1) the difference of limb-darkening coefficients in two colours; (2) the difference of the intrinsic colours of the two components of the eclipsing binary; and (3) the correction to the assumed colour index of the eclipsing binary immediately before the beginning of the eclipse or immediately after its end. The coefficients of these equations are almost independent of the orbital elements.'

ABSOLUTE DIMENSIONS OF ECLIPSING SYSTEMS

In Table 6 are listed the determinations of absolute dimensions published since the last report. Kopal, in Chapter VII of his book *Close Binary Systems* (2), gives the geometrical properties and absolute dimensions for 17 detached eclipsing systems; 10 semi-detached systems (secondary component in contact with the Roche limit); 19 single-spectrum systems with contact secondary components; 18 systems with 'undersize' sub-giant secondaries; and 8 systems of the R Canis Majoris type. Gaposchkin's chapter on eclipsing binaries (3) in the *Handbuch der Physik* contains a list of the absolute dimensions of 82 systems. Popper (7)

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lists 15 eclipsing binaries with well-determined absolute dimensions, 26 for which absolute dimensions are unlikely to be obtained and 40 others for which more observations are needed.

Table 6. New determinations of absolute dimensions of eclipsing binaries

Star	References
WW Aur	Popper, *Ap. J.* **129,** 664, 1959.
AR Aur	Popper, *Ap. J.* **129,** 664, 1959.
β Aur	Popper, *Ap. J.* **129,** 664, 1959.
UW CMa	Sahade, *P.A.S.P.* **71,** 151, 1959.
U Cep	Bolokadze, *Per. Zvezdy* **11,** 375, 1958.
Y Cyg	Magalashvili and Kumsishvili, *Bull. Abastumani Astrophys. Obs.* 24, 1959.
V 477 Cyg	Pearce, *Publ. Dom. astrophys. Obs.* **10,** 447, 1957.
31 Cyg	McKellar and Petrie, *Publ. Dom. astrophys. Obs.* **11,** 1, 1958.
DM Del	Schneller, *Astr. Nach.* **285,** 265, 1960.
TW Dra	Bolokadze, *Per Zvezdy* **11,** 375, 1958.
RX Her	Popper, *Ap. J.* **129,** 659, 1959.
CM Lac	Alexander, *Astr. J.* **63,** 106, 1958.
Y Leo	Johnson, *Ap. J.* **131,** 127, 1960.
XY Leo	Koch, *Astr. J.* **65,** 374, 1960.
U Oph	Abrami, *Mem. Soc. astr. Ital.* **29,** 381, 1958.
β Per	Hosokawa, *Publ. astr. Soc. Japan* **10,** 120, 1958; Arakeljan, *Bull. Burakan Obs.* 21, 1957.
ζ Phe	Hagemann, *M.N.R.A.S.* **119,** 142, 1959.
SZ Psc	Bakos and Heard, *Astr. J.* **63,** 302, 1958.
λ Tau	Grant, *Ap. J.* **129,** 78, 1959.
RW Tau	Grant, *Ap. J.* **129,** 62, 1959.
γ Vel	S. Gaposchkin, *Astr. J.* **64,** 127, 1959.
AH Vir	Binnendijk, *Astr. J.* **65,** 358, 1960.
α Vir	Struve, Sahade, Huang and Zebergs, *Ap. J.* **128,** 310, 1958.

For ζ Aur Lee and Wright (**47**) get a mass-ratio of 1·2 from the spectrum of the secondary, but the geometry of the system indicates a mass-ratio of 2. The spectrum of the secondary is B 6·5, and the luminosity $M = -1{\cdot}6$. From three-colour photometry of ζ Aur during the ingress of the 1955–6 eclipse Grant and Abt (**48**) found B 7 V for the spectrum of the secondary, and an absolute visual magnitude $-2{\cdot}2$ for the K 4 II primary. Popper writes that he has redetermined the masses of the components (using 35 spectrograms taken for the purpose) and finds $7{\cdot}9_{\odot}$ for the K super-giant, and $5{\cdot}5_{\odot}$ for the B star, both with an uncertainty of 15% and both appreciably smaller than previous estimates. He also mentions that RZ Eri does not have a metallic-lined component, as previously reported, but that, on the other hand, RR Lyn does have a metallic-line star as its brighter component. The lines of the fainter component are visible at D and Hα, so that for the first time the absolute dimensions of a typical metallic-lined star should be obtainable. Definitive light-curves in two colours are urgently needed.

Sahade (**49**) suggests that ϵ Aur may be a system formed by a super-giant F0 primary and an under-luminous secondary, the mass of which is either larger than, or not very different from, that of the primary.

THEORETICAL AND DYNAMICAL INVESTIGATIONS

Close binary systems have been the subject of many studies since the last report. Their origin and evolution are treated by Kopal in his recent book (**2**), (Chap. VII). Other discussions are by Abhyankar (**50**), Kopal (**51**), Krat (**51a**), Sahade (**52**), Smak (**53**), Struve (**54**), Walter (**55**) and Wood (**55a**). Kopal (**56**) discusses a group of eclipsing binaries similar to R Canis Majoris (RW Gem, T LMi, TU Mon, UU Oph, XZ Sgr, RZ Sct, S Vel), with abnormally small

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masses and with high space velocities, and suggests that they are in a later stage of evolution than the majority of close binaries. Sahade (**52**) suggests that W Ursae Majoris systems may be old objects which have evolved, through appreciable mass loss, from early-type systems (B or A stars).

Departures of components of W Ursae Majoris type systems from the mass-luminosity law are discussed in papers by Huruhata and Kitamura (**57**), Kitamura (**58**), Sahade (**49**) and F. B. Wood (**59**). In a recent letter Wood writes:

'I have been giving some thought to the large departures from mass-luminosity found in so many eclipsing systems. It seems to me that in general the efforts to explain these by mass transfer are leading to blind alleys, although such transfer could conceivably cause the period changes. A more promising line of approach seems to me to be consideration of the conditions existing during the final condensation stages of the stars. In other words, instead of evolving into this condition, let us consider whether the dynamical conditions at the time of formation might be such that close double stars can frequently be formed in this way. The preliminary results of these considerations look good but a great deal more work remains to be done before anything really definite can be said.'

Dynamical interaction between the components and mass transfer in close binary systems are the subject of studies by Kopal (**2**), Abhyankar (**60**), Reddish (**61**), and Struve (**62**). Kitamura (**63**) has constructed stellar models which are mass-accumulating and gravitationally contracting, for application to secondary components which are over-luminous for their masses and which have reached their Roche limits. A completely radiative model is found to resemble a single giant star. A model with radiative core and convective envelope was found to be consistent with the secondary components of 44 i Boo, TX Cnc, VW Cep and W UMa. It would follow that the lifetime of W Ursae Majoris stars is about 10^7 years, as compared with 10^8 years proposed by Sahade (**52**). Morton (**64**) proposes a model in which the primary component evolves first to the Roche limit and then transfers most of its mass to the other star, so that the roles of primary and secondary are interchanged. The transition is so rapid that it would be difficult to observe.

The dynamics of matter ejected from unstable components are treated by Kopal (**2**), Gould (**65**), and Prendergast (**66**), who treats the subject by the methods of hydrodynamics, instead of particle mechanics as has been done hitherto. Other papers on the nature and origin of gas streams in close binaries are by Gunther (**67**) and Kopal (**68**). Struve (**69**) has pointed out the great amount of information about these gaseous streams that is obtained from the study of Hα emission (and absorption) in close eclipsing binaries. Studies of this kind have been made, largely by Struve and his school, on the following eclipsing binaries: UW CMa (**54**), AO Cas (**70**), TZ CrA (**59**), U CrB (**71**), V 448 Cyg (**69**), YY Gem (**72**), β Per (**73**), RZ Sct (**74, 75, 76**), HD 47129 (Plaskett's star) (**77**). Sahade writes: 'The study of Plaskett's star specially in the region of Hα enabled us to suggest a model for the system. There exists a gaseous stream from the secondary towards the following hemisphere of the primary component, and this stream is strongly deflected about 90° relative to the radius vector joining the two stars. The matter from this stream forms an expanding envelope to the system which produces strong largely violet-displaced absorption lines in part of the cycle. These displaced absorptions were found for the first time in this star.' Sahade and Frieboes find, from spectra taken at Bosque Alegre, that V Pup is a system with gaseous streams at work; the secondary component is probably a sub-giant star.

Eggen (**78**) determined magnitudes and colours for 46 contact binaries, in order to investigate the period-colour relation. He finds a sharp cut-off in period near $0^d{\cdot}2$, a well-established discontinuity at $P=0^d{\cdot}65$ and a dichotomy for periods greater than $0^d{\cdot}65$, which may indicate

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that the early-type binaries occur predominantly in two groups. The observed period-colour relation agrees in part with the theoretical relation, derived by Eggen, but for binaries with periods between $0^{d}{\cdot}3$ and $0^{d}{\cdot}65$ the slopes of the two curves differ. As a possible explanation of this anomaly Eggen makes the interesting suggestion that contact binaries in this range may be in the post-T Tauri stage of evolution. He puts forward various pieces of evidence that point in this direction.

Rigal (**79**) finds that the mean depth of the eclipses of W Ursae Majoris type stars does not vary appreciably with the period. To account for this, he suggests the existence of a very luminous zone, the extent of which would vary little with the separation of the components.

Popper (**80**) has compared the fundamental properties of four A-type eclipsing binaries, RX Her, WW Aur, AR Aur and β Aur, with those of nearby stars of the main sequence. He finds excellent agreement between the eclipsing binaries and single stars in the colour-spectrum, mass-luminosity and colour-luminosity relations. Kreiken and Süer (**81**) discuss the possibility of obtaining information about stellar evolutionary tracks from a study of binary and multiple systems.

Popper points out that nearly all well-investigated systems, with one component a sub-giant near K0, show intrinsic variations, *e.g.* AR Lac, Z Her, RS CVn. He suggests that it would be interesting to know whether such poorly observed systems as SS Cam, AD Cap, MM Her, AW Her and VV Mon also show intrinsic variations.

Herbig (**82**) finds that the very short period variable VV Pup is probably an eclipsing binary. Its period (100 minutes) is shorter than that of any other eclipsing binary yet known. Evans (**83**) finds for HD 16157, which is probably an eclipsing binary of very unusual type, the extremely low mass-function $0{\cdot}0087_{\odot}$.

STATISTICAL AND SPECTROPHOTOMETRIC INVESTIGATIONS

Kraft and Landolt (**84**) give a list of 26 eclipsing binaries in galactic clusters and of 577 found in optical coincidence with O-B associations. Sahade and Frieboes (**85**) have carried out a search for W Ursae Majoris type stars in galactic clusters and have found 16 possible members. Batten (**86**) discusses a possible local grouping of eclipsing binaries.

The earliest eclipsing variables discovered, *Algol* and β Lyrae, archetypes of two main classes of eclipsing binaries, are both systems with many complications, which are the subject of constant study. Struve devoted his 1957 H. N. Russell lecture (**87**) to the problem of β Lyrae. Sahade (**88**) proposed a new model of the system, which is further elaborated in the important study of the spectrum by Sahade, Huang, Struve and Zebergs (**89**). The primary component, a B giant, is the less massive star of the system and is in the expanding stage of its evolution; the secondary component was probably always the more massive star and, therefore, must have evolved faster, reached the end of its evolutionary track to the right, evolved to the left and is now under-luminous for its mass. The spectrum of the secondary shows only broad emission lines.

Algol, and in particular *Algol* C, has been the subject of investigations by Ebbighausen (**90**), Herczeg (**40, 91**), Hosokawa (**92**) and Segre (**93**). An exhaustive study of the period of *Algol* by Kopal, Plavec and Reilly (**94**) is based on more than 1500 minima. They conclude that, while the 32-year period in the *Algol* system can be adequately explained in terms of apsidal motion, the 'great inequality' in the observed times of the light minima, with a period of about 160 years, is due to a cause, or causes, unknown.

One of the most interesting discoveries in our field in recent years is that made by Walker, that Nova DQ Herculis is an eclipsing binary. Struve (**95**) has summarized our knowledge of

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it. Any information about its behaviour in the pre-Nova stage would be valuable. Ahnert (**96, 97**) from measures on pre-outburst photographic plates, obtained seven epochs of minimum, which he considers probably real; they are consistent with a period $0^d{\cdot}0004$ shorter than that found by Walker after the Nova outburst. Herczeg (**98**), on plates taken during the minimum which occurred not long after the outburst, found evidence of a minimum of eclipse type at the time computed by Walker's elements. In the early stages after the outburst the Nova was of course much too bright for such an eclipse minimum to be perceptible.

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