42. CLOSE BINARY STARS (ETOILES DOUBLES SERREES)

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1. Introduction

Interest in close binary stars continues to grow apace. Substantial fractions of the observing time on the International Ultraviolet Explorer and the various X-ray satellites have been devoted to extending our knowledge of a variety of interacting binaries. These, together with applications of novel ground-based techniques and the steady improvement of traditional methods, and developments in methods of analysis, have led to major advances in understanding of the properties and evolution of close binary stars.

Our Symposium *Close Binary Stars* held in Toronto, 7-10 August 1979, was attended by 170 participants from 26 countries and over 100 papers were presented. The proceedings have been published as IAU Symposium No. 88, *Close Binary Stars: Observations and Interpretation*, eds. M. Plavec, D.M. Popper and R.K. Ulrich; Reidel Publishing Co., 1980.

Commission 42 is sponsoring a meeting, IAU Colloquium No. 72, *Cataclysmic Variables and Related Objects*, to be held in Israel 9-13 August 1982. This is co-sponsored by Commissions 27, 35 and 48.

Meetings which have been co-sponsored by Commission 42 are IAU Symposium No. 93, *Fundamental Problems in the Theory of Stellar Evolution*, held in Kyoto, Japan, 22-25 July, 1980; IAU Colloquium No. 69, *Binary and Multiple Stars as Tracers of Stellar Evolution*, held in Bamberg, Germany, 31 August-3 September, 1981; IAU Colloquium No. 70, *The Nature of Symbiotic Stars*, held at Haute Provence, France, 26-28 August, 1981; IAU Colloquium No. 71, *Activity in Red-spotted Stars*, held at Catania, Italy, 10-13 August, 1981; and IAU Symposium No. 99, *Wolf-Rayet Stars: Observations, Physics and Evolution*, held in Cozumel, Mexico, 16-22 September, 1981.

Other Meetings, the published proceedings of which will have interest to Commission members, are *Photometric and Spectroscopic Binary Systems* (eds. E.B. Carling, and Z. Kopal, Reidel, Dordrecht, 1981); IAU Colloquium No. 53, *White Dwarfs and Variable Degenerate Stars*, held at Rochester, USA, 31 July-3 August, 1979; IAU Colloquium No. 59, *Effects of Mass Loss on Stellar Evolution*, held in Trieste, Italy, 15-19 September, 1980; and the IAU Regional Meetings *Variability in Stars and Galaxies*, held in Liege, Belgium, 28 July-1 August, 1980 and the 2nd Asian-Pacific Regional Meeting held in Bandung, Java, 24-29 August, 1981.

Workshops on cataclysmic variable stars were held in Rochester, USA, on 3 August, 1979; in Austin, USA on 24-26 March, 1980; and in Santa Cruz, USA, 12-31 July, 1981. No proceedings were published from these meetings.

Other proceedings published in the period 1979-81 include *Sistemas Binarios Cerrados* (Colloquium on close binary stars held at Sao Paulo, February 1977), ed. R.V. de Moraes, Inst. Astr. et Geofis., Sao Paulo; *Close Binaries and Stellar Activity* (Joint Commission Meeting at the 1979 Montreal IAU General Assembly), Highlights of Astronomy, Vol. 5, Reidel; *The Cataclysmic Variables and Related Stars*

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(meeting held at Kyoto University, 24-25 February, 1981), published (in Japanese) by Kyoto University.

Observers were greatly assisted by the publication in 1979 of the 5th edition of *A Finding List for Observers of Interacting Binary Stars*, by F.B. Wood, J.P. Oliver, D.R. Florkowski and R.H. Koch (University of Pennsylvania Press). From this list, the authors have selected a number of objects that appear particularly in need of further observation (*IBVS* No. 1708). Z. Kopal's monograph, *Language of the Stars: a discourse on the theory of eclipsing variables*, was published as Vol. 77 of the *Astrophysics and Space Science Library* (Reidel).

The *Bibliography and Program Notes on Close Binaries* continued to be issued from Lund Observatory, edited by G. Larsson-Leander. Nos. 32-35 appeared during the triennium. The regional contributors were K.D. Abhyankar (India and Indonesia), B. Cester (Italy), D.S. Hall and G.W. Henry (USA, except the west coast), M. Kitamura (Japan, China and Korea), H. Mauder (Germany and the *IAU Circulars*), C.D. Scarfe (Canada, USA west coast, Mexico), A. Schulberg (USSR), R.F. Sisteró (Southern Hemisphere), F. van't Veer (Western Europe), and M. Vetešnik (Central and Eastern Europe, except Germany and USSR).

This Report has been compiled principally from sections written by members of the Organizing Committee, and is based on published literature and information contributed by members of the Commission. In addition, Drs. D.M. Gibson and R.W. Hilditch kindly provided the sections on Radio Observations and Algols respectively. Because of limitations of space, not all the information received has been incorporated in the Report.

Key to the references:

AA = *Acta Astron.*
AAp = *Astron. Astrophys.*
AAp Sup = *Astron. Astrophys. Suppl. Ser.*
AA Sin = *Acta Astron. Sinica*
AJ = *Astron. J.*
AN = *Astron. Nachr.*
Ann Rev AAp = *Ann. Rev. Astron. Astrophys.*
Ann Tokyo = *Ann. Tokyo Astron. Obs., Second Ser.*
ApJ = *Astrophys. J.*
ApJ Sup = *Astrophys. J. Suppl. Ser.*
ApL = *Astrophys. Lett.*
ApSpSc = *Astrophys. Space Sci.*
ATs = *Astron. Tsirk.*
AZh = *Astron. Zh. Akad. Nauk USSR*
BAAS = *Bull. American Astron. Soc.*
BAC = *Bull. Astron. Inst. Czechoslovakia*
BASI = *Bull. Astron. Soc. India*
IAUC = *IAU Circ.*
IBVS = *Inf. Bull. Variable Stars*
Izv Krym = *Izv. Krymskoj Astrofiz. Obs.*
JRASC = *J.R. Astron. Soc. Canada*
MittAG = *Mitt. Astron. Ges.*
MN = *Mon. Not. R. astr. Soc.*
MSAI = *Mem. Soc. Astron. Italiana*
Obs = *Observatory*
PASJ = *Publ. Astron. Soc. Japan*
PASP = *Publ. Astron. Soc. Pacific*
PerZv = *Perem. Zvezdy, Byull.*
Pis AZh = *Pis'ma v Astron. Zh.*
Publ DAO = *Publ. Dominion Astrophys. Obs.*
Publ Tartu = *Publ. Tartu Astrofiz. Obs.*
S&T = *Sky and Telescope*
Trudy Kazan = *Trudy Kazan. Gorod. Astron. Obs.*

2. Observational Techniques

Close binaries continue to be observed by almost every available technique. Details of spectrographic, photometric, polarimetric, X-ray and radio observations may be found in later Sections.

In spectrography, the introduction of digital electronic methods (e.g. Reticons, Digicons) has led to tremendous improvements in sensitivity, signal-to-noise and consequent time resolution, particularly in the area of cataclysmic variables (Stover *et al.*, *ApJ 240*,597; Young *et al.*, *ApJ 244*,259). The extended red response of these digital spectrographs has resulted in the detection of the red companions in a number of objects (Stauffer *et al.*, *PASP 91*,59; Wade, *ApJ 246*,215 and *AJ 84*, 562; Young and Schneider, *ApJ 247*,960). At very high resolution, digital coudé spectra have been obtained of U Cep (Lambert & Tomkin, *MN 186*,391) and infrared Fourier Transform spectra have shown CO emission in Nova NQ Vul (Ferland *et al.*, *ApJ 227*,489).

High time resolution photometry continues to be extensively applied (see Section 6D). A novel application by Hildebrand *et al.* (*ApJ 248*,268) determined the colours of the fast oscillations in AH Her. The first application of DDO photometry to W UMa systems was made by Hilditch (*MN 196*,305).

An extensive search for polarization in cataclysmic variables has been made by Stockman *et al.* (*ApJ* in press). Spectropolarimetry of AMHer (Schmidt *et al.*, *ApJ 243*,L157) led to detection of Zeeman splitting in the Balmer absorption lines.

A review of ultraviolet observations of close binaries from space has been given by Kondo (*Highlights 5*,849). Ultraviolet photometry from OAO 2, including, e.g. AG Peg, was reported by Gallagher *et al.* (*ApJ 229*,994). Extensive use of IUE has been made, the details of which are given in Section 6B.

X-ray satellite observations (see Section 4D) led to the detection of X-rays from RS CVn stars (Walter *et al.*, *SAO Special Rept.* No. 389). An X-ray survey was made for cataclysmic variables (Becker and Marshall, *ApJ 244*,L93) and several more are in press. 33-sec X-ray pulsations were detected in AE Aqr (Patterson *et al.*, *240*,L133).

Co-ordinated optical, UV and X-ray observations were carried out by Fabbiano *et al.* (*ApJ 243*,911), Hutchings (*PASP 92*,458), Szkody *et al.* (*ApJ 246*,223) and Szkody (*ApJ 247*,577).

Speckle interferometry of Algol was obtained by McAlister and De Gioia (*ApJ 228*,493) and Bonneau (*AAp 80*,L11).

VLBI and VLA radio observations (Section 4E) include the detection of triple structure in an X-ray burster (Hjellming & Eurald, *ApJ 246*,L137) and Sco X-1 (Geldzahler *et al.*, *AJ 86*,1036) and jets in SS 433 (Section 4E).

3. Methods of Analyzing Light Curves
(G. Larsson-Leander)

During the past triennium, the methods of analyzing light changes in the frequency domain were pursued vigorously, primarily by Kopal and his present and previous collaborators. A very brief description of the methods was attempted in the 1979 Report, mainly based on the then published papers in the series "Fourier Analysis of the Light Curves of Eclipsing Variables" (*ApSpSc*). A full description of the methods developed by Kopal and his school is now available in Kopal's monograph *The Language of the Stars* (D. Reidel, Dordrecht, 1979). Further papers have also been published in the series mentioned above. Alkan (*ApSpSc 58*,453) presented another method to evaluate the α_i^0-functions numerically, Demircan (*ApSpSc 59*,313) deduced new properties of the α_i^0 and the moments A_{2m} and developed an iterative method to solve the fundamental eclipse parameters a and c_0 in terms of observed quantities. The so-called g-functions, which have a and c_0 as arguments, were discussed by Edalati (*ApSpSc 59*,333) from a theoretical point of view, and he gave in another paper (*ApSpSc 59*,443) numerical results pertaining to the determinacy of solution for the geometrical elements. Photometric perturbations from distortions due to axial rotation and tidal action were considered by Alkan and Edalati (*ApSpSc 59*,431), and the error analysis was treated by Kopal (*ApSpSc 66*,91). In the latest paper of the series (No. XXVI), Kopal and Yamasaki (*ApSpSc 72*,3) gave analytical expressions for the incomplete Fourier transforms underlying Kitamura's 1965 method. The numerical coefficients, tabulated by Kitamura 1967, were checked and found of high quality.

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In another series of papers, Demircan (*ApSpSc 61*,499,507,*62*,189,235,*67*,367,375, *72*,281,287) suggested modifications to the Kopal procedure and discussed various alternative series developments of the loss of light ($1-l$) in terms of the elements. In addition to Kopal's integral transform A_{2m}, generalizations were made by introducing either an exponential or a Jacobi polynomial as multiplicative factor into the integrand. Other integral transforms were also used. As pointed out by Demircan, principally the same solution should be obtained by using any of the transforms, but in practice this may not be so, because the geometric determinacy of the elements will be different in different transforms.

In the opening paper of still another series, "Linear Analysis of the Light Curves of Eclipsing Variables", Kopal and Sharaf (*ApSpSc 70*,77) considered model analysis for the fractional loss of light in the sense of the least-squares criterion. Other contributions to the Fourier techniques include a study by Rovithis-Livaniou (*ApSpSc 59*,463) of the photometric perturbations for partial eclipses and a generalization by Niarchos (*ApSpSc 76*,503) of the Kopal method to evaluate the proximity effects.

Smith and Theokas (*ApSpSc 70*,103) developed a method to solve for atmospheric eclipses, using either the A_{2m} or the A_{2m}-moments, previously introduced by Smith.

The Fourier techniques were applied to many eclipsing systems, and in most cases the papers have been published in *ApSpSc*. These methods also dominated the NATO Advanced Study Institute at Maratea, Italy, in June 1980, the proceedings of which were printed as *Photometric and Spectroscopic Binary Systems* (see Introduction). This book contains, *i.a.*, an extensive discussion by Jurkevich *et al.* of the error analysis of the elements, and papers by Demircan, Zafiropoulos, Rovithis-Livaniou, and Niarchos on various topics of the theory. A computer program for the frequency-domain analysis is presented by Giménez and García-Pelayo.

The well established synthesis methods for analyzing light curves were used extensively by many groups. It appears that D.B. Wood's code WINK and the Wilson-Devinney (WD) code hold their positions as most popular among the users. Wilson (*ApJ 234*,1054) generalized the WD code to include eccentric orbits and non-synchronous rotation. Semi-detached, detached, double-contact, and X-ray binaries can now be modelled for arbitrary rotation and orbital eccentricity. For contact binaries the models are restricted to the synchronous, circular-orbit case. It is possible to obtain the differential corrections solutions to the light and radial-velocity curves simultaneously.

Hill (*Publ DAO 15*,297) described his computer program (LIGHT), which is based on Roche geometry and is suitable for contact and under-contact systems, although over-contact systems can be handled approximately. Passbands, simulating instrumental response functions, can be synthesized by convolving given response functions with light curves calculated at up to 30 wavelengths.

A relatively simple code was developed by Napier (*MN 194*,149), adopting the ellipsoid-ellipsoid model and treating the reflection effect semi-analytically. Etzel, in the Carling-Kopal book mentioned above, described a fast and flexible method (EBOP) for treating well-detached systems. It has been used with success by Etzel and Popper. When compared with WINK, it is more accurate for spherical stars and 15-40 times faster.

4. Observational Data

A. PHOTOMETRIC OBSERVATIONS AND SOLUTIONS (R.H. Koch)

This section was compiled from materials held at the University of Pennsylvania by June 30, 1981 and is intended to provide continuity with the 1979 version prepared by T. Herczeg. The earlier version occupied about 2.5 pages with most of its

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content in Tables 1 and 2 *Photoelectric Observations* and *Photometric Solutions*, respectively.

Photoelectric observing has increased dramatically in the last triennium as may be seen from the first two entries of the present Table 1, which refers to spacecraft UV through *L*-band radiometry and conforms to Herczeg's precept of citing references which contain a "considerable amount" of new data. No increase of space has been allocated for the 1982 report and thus a presentation analogous to Herczeg's Table 1 is impossible. (Such a table has actually been compiled in manuscript form and could be made available upon request. However, it is my belief that, had the pressure of space not even existed, the broad distribution and acceptability of *The Bibliography and Program Notes on Close Binaries* make the familiar Table 1 an anachronism).

It is worthwhile to examine the photoelectric effort in order to see some effects of so much work. The first and third entries of Table 1 show that ≃100 binaries observed from 1975 to 1978 were re-observed in the following 3 years. This is

Table 1. Photoelectric Observing Programs for the Past Two Triennia

	1975-1978	1978-1981
Close binaries observed	209	342
References for photoelectric data	346	564
Binaries not observed 1975-1978	-	240
Northern systems ($\delta > +23^{\circ}$)	88	120
Equatorial systems	50	77
Southern systems ($\delta > -23^{\circ}$)	35	76

a healthy statistic for a large number of objects show time-dependent behaviour that is not phase-locked to the Keplerian period, and the accumulation of such photometric history continues to be an important function of the Commission. Even more impressive, however, are the 240 binaries studied again after an interval of at least 3 years or studied for the first time. There can be no doubt that interesting and extreme objects are now accessible to the larger, better-sited telescopes equipped with modern detectors and improved data handling procedures. Efforts to move toward ever-fainter binaries will be rewarding.

The last 3 entries of Table 1 show that the increase of observing effort has been achieved in an absolute sense all over the sky, and that there has been a substantial relative gain in coverage of the southern constellations.

A few new, archival photographic light curves are likely to be enduringly important: KR Aur *AJ 85*, 1092; V1329 Cyg *IBVS* 1525; V1357 Cyg *BAC 30*,250; V3885 Sgr *PASP 90*,216; NJL5 *IBVS* 1527; and A0538-66 *Nat 288*,147.

There appears still to be a need for a summary of photometric solutions and this appears in the following Table 2 listing citations for essentially non-dimensional analyses or syntheses of light curves. In the present usage, "non-dimensional" implies that investigations of light curves founded primarily upon scaled (e.g., in c.g.s. units or in solar units) are not included in the table.

Since 1978 the number of light curve studies has not increased so much in a relative sense as has the number of photoelectric data sets. Nonetheless, there has been a 25% increase in the number of light curve solutions in just these 3 years. This is due primarily to the increasing number of groups studying new and historical light curves by computerized methods. It is instructive to see in Table 3 the use that has been made of the assortment of computational procedures now available. The percentages in the table have been rounded to $\pm 1\%$ and methods with a utilization smaller than 2% have been collected in the Miscellaneous category. In characterizing these procedures by so few authors some omissions of significant contributions by

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Table 2. Photometric Solutions

RT And *AApSup 36*,415, *ApSpSc 66*,475; TW And *AApSup 39*,265; AB And *ApSpSc 58*,301; ST Aqr *IBVS* 1790; KO Aql *PASJ 31*,271, *IBVS* 1916; OO Aql *ApSpSc 58*,301; QY Aql *ApSpSc 76*,111; V805 Aql *AJ 86*,102; RW Ara *AApSup 29*,273; V535 Ara *ApSpSc 58*,301, *AApSup 36*,287; V539 Ara *AApSup 36*,45, *39*,255, RX Ari *AApSup 42*,195; SX Aur *ApSpSc 63*,351, *ApJ 228*,828, BF Aur *AJ 84*,236, EO Aur *ApSpSc 70*,461, IM Aur *AApSup 40*,57; IU Aur *AApSup 37*,513; LY Aur *AA 28*,195; SU Boo *AApSup 40*,59, TY Boo *ApSpSc 58*,301; TZ Boo *AApSup 33*,63, *MittAG 45*,49; VW Boo *ApSpSc 58*,301, XY Boo *ApSpSc 58*,301; Y Cam *AAPSup 39*,265; SS Cam *AA 29*,243; SV Cam *MN 187*,797; SZ Cam *AAp 86*,264, *BAC 31*,321, *ApSpSc 76*,23; TU Cam *AApSup 42*,15; AS Cam *ApSpSc 59*,3, *AApSup 39*,255; AY Cam *IBVS* 1613; TX Cnc *ApSpSc 77*,75; WY Cnc *ApSpSc 63*,479; AH Cnc *MN 186*,729; RS CVn *ApJ 227*,907; R CMa *AApSup 36*,273; CW CMa *AApSup 42*,15; FZ CMa *AAp 94*,201, YY CMi *AAp 94*,391; OY Car *AAp 85*,362, *94*,L29; QZ Car *ApJ 231*,742; RX Cas *Publ Tartu 58*,3; TV Cas Trudy Kasan *42-43*,72, *AApSup 39*,273; TW Cas *AApSup 39*,235, YZ Cas *AApSup 42*,15; AB Cas *ApSpSc 71*,249; CW Cas *ApSpSc 58*,301; HT Cas *BAAS 11*,664, OX Cas *ATs* 1033, *AAp 82*, 386; PV Cas *ApSpSc 75*,455; V523 Cas *Trudy Kasan 42-43*,46, *AJ 86*,98, RR Cen *ApSpSc 58*,301, U Cep *MN 187*,699, *AApSup 40*,135; VV Cep *Ann Tokyo 17*,147, *PASJ 32*,163; VW Cep *ApSpSc 58*,301, *IBVS* 1686; XY Cep *ApSpSc 66*,143; EK Cep *Trudy Kasan 44*,96, *AApSup 42*,15; NY Cep *JRASC 73*,258; TV Cet *AAp 72*,356, TY Cet *AJ 86*,102; XX Cet *AApSup 39*, 235; XY Cet *ApSpSc 56*,293, *71*,385; Z Cha *AA 29*,309, RS Cha *AAp 83*,339, *85*,259, RZ Cha *AAp 85*,259; RZ Com *ApSpSc 58*,301, CC Com *ApSpSc 58*,301; RW CrA *BAC 31*,297, TZ CrA *AApSup 42*,195; RW CrB *AApSup 40*,57; *42*,195; W CrV *ApJ 231*,502; AI Cru *ApSpSc 71*,411, *77*,197; 32 Cyg *PASP 91*,343; Y Cyg *AApSup 39*,255; SW Cyg *AApSup 39*,265, UZ Cyg *AA 29*,259; VW Cyg *AA 29*,259, *AApSup 39*,273; WW Cyg *AApSup 39*,265; CG Cyg *ApSpSc 67*,11; DK Cyg *ApSpSc 58*,301; KR Cyg *AApSup 42*,195; MY Cyg *AApSup 39*,255, *AJ 86*,102; V380 Cyg *ApSpSc 71*,385; V382 Cyg *BAAS 11*,439; V388 Cyg *ApSpSc 76*,111; V444 Cyg *AZh 57*,1033, V477 Cyg *ApSpSc 59*,3; V478 Cyg *AJ 86*, 102; V548 Cyg *AApSup 39*,235, *ApSpSc 77*,391, V729 Cyg *ApJ 224*,565; V1073 Cyg *ApSpSc 58*,301; V1143 Cyg *ApSpSc 59*,3; *AJ 86*, 102, V1341 Cyg *ApJ 231*,539; *AA 30*,143; V1357 Cyg *ApJ 226*,264, *229*,296, *ATs* 1095, W Del *AApSup 39*,273; RZ Dra *AASin 21*,158; TW Dra *ApSpSc 73*,389; WW Dra *AApSup 39*, 273; AI Dra *ApSpSc 39*,265; AR Dra *AApSup 37*,487; BS Dra *AApSup 36*,65, *IBVS* 1794. *AJ 86*,102, S Equ *AApSup 36*,273; RU Eri *ApSpSc 74*,41; UX Eri *ApSpSc 58*,301 WX Eri *ApSpSc 65*,443; YY Eri *ApSpSc 58*,301; CD Eri *ApSpSc 67*,213; CW Eri *AApSup 42*,15; U Gem *AA 30*,127; RW Gem *AApSup 36*,273; AL Gem *AApSup 36*,273; u Her *AA 28*,601, *AAp 81*,17, RX Her *AApSup 42*,285; UX Her *AApSup 40*,57; AD Her *AAp Sup 39*, 235; AK Her *ApSpSc 58*,301, *PASP 91*,234; *ApJ 231*,502; AM Her *AAp 70*,327; *ApJ 230*,502, *MN 194*,187; DI Her *ATs* 1016; DQ Her *AZh 57*,749; *AA 30*,267, *ApJ 241*,247; HS Her *ApSpSc 76*,111; LT Her *AAp 79*,354; V338 Her *AApSup 39*,273; V624 Her *AApSup 39*,255; AV Hya *BASI 7*,119, *ApSpSc 76*,173; EU Hya *BASI 7*,119; HS Hya *AAP 85*,259; 16 Lac *IBVS* 1552, RT Lac *ApJ 227*,907, SW Lac *ApSpSc 58*,301; CO Lac *AApSup 42*,15; EM Lac *ApSpSc 58*,301; Y Leo *IBVS* 1786; UZ Leo *ApSpSc 58*,301, Am Leo *ApSpSc 58*,301; AP Leo *IBVS* 1688; T LMi *AApSup 36*,273; δ Lib *AApSup 37*,513; SW Lyn *IBVS* 1801, FL Lyr *PerZv 20*,588, *AApSup 39*,235; TY Men *AJ 85*,1098; TZ Men *AAp 94*,204; RW Mon *AApSup 39*,273; VV Mon *AApSup 35*,291; AO Mon *AApSup 39*,255, TU Mus *ApSpSc 76*,23; UZ Oct *AApSup 38*,171; *MittAG 50*, 30; RV Oph *AApSup 39*,273; V451 Oph *AApSup 39*,255; V502 Oph *ApSpSc 58*,301; V566 Oph *ApSpSc 58*,301; V839 Oph *ApSpSc 58*,301; VV Ori *ApSpSc 72*,369, ER Ori *ApSpSc 58*,301; MW Pav *AJ 85*,1098, U Peg *ApSpSc 58*,301; AQ Peg *AA 29*,259; BB Peg *AApSup 40*,85; BK Peg *AJ 86*,102; DI Peg *AAp 91*,254, *AApSup 42*,195; EE Peg *AApSup 42*,15, b Per *AA 29*, *225*; β Per *ApSpSc 60*,441, *AAp 89*,100; RT Per *ApSpSc 58*,3, *59*,443, *BASI 7*,118, *ApSpSc 75*,329; ST Per *AApSup 39*,273; AG Per *ApSpSc 57*,17, IQ Per *AApSup 42*,15; IW Per *ApSpSc 68*,355; IZ Per *Trudy Kasan 44*,96, *AApSup 40*,57; AD Phe *MittAG 45*,49; AE Phe *ApSpSc 58*,301, δ Pic *ApSpSc 76*,23, Y Psc *AApSup 39*,265, SZ Psc *ApJ 227*,907, UZ Psc *ApSpSc 63*,319; RW PsA *ApJ 231*,502; V Pup *AJ 84*,236; XZ Pup *AApSup 39*,265; UU Sge *ApSpSc 73*, 83; WZ Sge *MN 184*,835; *AAp 76*,168, *AA 29*,325; XZ Sgr *AApSup 36*,273, *38*,161, *IBVS* 1827; V505 Sgr *AApSup 39*,273, μ^1 Sco *AJ 84*,236; V499 Sco *ApSpSc 76*,23; RT Scl *BAAS 12*,748; RW Tau *AApSup 40*,57; RZ Tau *ApSpSc 58*,301; CD Tau *AApSup 40*,145; HU Tau *IBVS* 1740, V471 Tau *ApSpSc 57*,219, *AJ 86*,572; HO Tel *BAC 31*,297; X Tri *AApSup 39*,265; W UMa *ApSpSc 58*,301; *ApJ 239*,919; UX UMa *ApJ 241*,247; VV UMa *AApSup 40*,57; XY UMa

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IAU Symp 88,423; AW UMa *AJ 85*,50, *IBVS* 1802; W UMi *AApSup 40*,57; S Vel *IBVS* 1634, *AApSup 36*,273; AH Vir *ApSpSc 58*,301; BH Vir *AApSup 39*,255, *42*,195; BE Vul *AApSup 40*, 57; BS Vul *AApSup 35*,63; ER Vul *AApSup 43*,85; HR 5110 *AJ 85*,1082; HR9049 *ApSpSc 74*, 83; CPD-60°389 *AA 30*,113; HD5980 *ATs* 1047, HD152667 *AAp 70*,L49; ω Cen V78 *ApSpSc 64*, 427; HDE269696 *MN 183*,523; *AA 30*,113; LB3459 *MN 187*,1; *AA 30*,113, Cen X-3 *ApJ 226*, 264; 4U1223-62 *ApJ 226*,264; 4U1626-67 *ApJ 226*,264; SS443 *MN 194*,293; LMC X-4 *ApJ 226*, 264; SMC X-1 *ApJ 226*,264.

Table 3. Percentages of Light Curves Studied by Different Computational Methods 1978-1981

Hill	2%
Horak	2%
Kitamura	4%
Kopal	17%
Miscellaneous	15%
Nelson-Davis Etzel	2%
Russell-Merrill	11%
Wilson-Devinney	14%
Wood	34%

unnamed workers have been inevitable. It is apparently a common experience that the speed of the Russell-Merrill χ-functions offers a convenient and useful initialization of parameters for other codes if the eclipses are sufficiently geometrically deep. The wealth of these different procedures now offers opportunity to scrutinize the strengths and defects of each procedure in order to determine its limits and, if possible and necessary, to ramify the physical model to which each procedure is applied. Comparative studies of specific light curves by different procedures appear rather commonly among the citations in Table 2.

One of the most heartening developments is the ingenuity underpinning many *ad hoc* procedures collected above as Miscellaneous ones. For the most part, these have been applied to atmospherically-eclipsing systems, cataclysmic variables, and spotted star systems and have required parameterization beyond the conventionally interacting two-body system.

B. SPECTROSCOPIC AND SPECTROPHOTOMETRIC INVESTIGATIONS (A.H. Batten)

Table 4 is a list of references to spectroscopic and spectrophotometric studies of binary systems, made in the triennium under review. It has not been possible to observe exactly the prescribed limits for the review period. References to *IAU Circulars* have not been given, and references to published abstracts have been dropped when it could be clearly ascertained that the full paper has been subsequently published. An asterisk following a reference indicates that an orbital study is to be found in it. Spectroscopic studies of optical counterparts of X-ray sources have been included in the Table, but no attempt has been made in this section to provide complete references to such objects. The growing need for some standard nomenclature for faint objects is very apparent in the Table.

Research in this field continues at a very high level of activity. Our knowledge of late-type, long-period (and mostly single-spectrum) systems has been vastly increased by the application of radial-velocity spectrometers, particularly but not exclusively, by Griffin himself. New statistical studies of these systems will soon be needed. The application of the objective-prism to the study of binary stars has been revived and modified by Gieseking. To save space, by avoiding frequent reiteration of the same reference, his important paper in *AApSup 43*,33 has not been included in Table 4. The orbital studies of 27 spectroscopic binaries contained in it should not, however, be overlooked.

Systems containing Wolf-Rayet stars have continued to attract interest. Conti, Massey and Niemela, on the one hand, and Moffat and Seggewiss, on the other, have studied several. Massey's work has led to an important summary of information on

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the masses of these objects (*ApJ 246*,153). Evidence is mounting that not all Wolf-Rayet stars are members of close binary systems.

Studies in the far ultraviolet have been increasingly made in the past few years. Two sources of important papers that did not come to hand soon enough to be fully incorporated into Table 4 are: *ESA SP 157 (Proceedings of the 2nd European IUE Conference)* and *NASA Conference Publications 2171* (The First Two Years of IUE). Additional important papers on several systems will be found in these two volumes. Plavec and his associates report considerable progress in their ultraviolet studies of Algol-type systems. They have also studied the "Serpentid" group (named after an early example, W Ser). Far UV spectra of this latter group are characterized by strong emission lines of ionized heavy elements. Systems whose visible spectra are as diverse as those of β Lyr, SX Cas and W Ser, appear to have closely similar UV spectra. On the other hand, the UV spectra of Algol-type systems tend to agree with the spectral types assigned to the visible spectra except that sometimes strong absorption lines of higher excitation than expected are seen. Plavec and Keyes also find strong evidence for the binary nature of many symbiotic stars.

The RS CVn group continues to attract attention and this is especially reflected in the prominence of V711 Tau (HR 1099) in Table 4. The Table also reflects the excitement generated by SS 433, although detailed discussion of that object is out of place in this section. At the opposite extreme we might point to the spectroscopic studies of selected visual binaries by Batten, Fekel, Scarfe and West.

Table 4

Z And *IBVS* 1636, *MSAI 50*,221, *IAU Symp 88*,543; AN And *Izv Krym 59*,143- EG And *ApJ 237*,831, *Nature 284*,148; ET And *IBVS* 1600*,1657, α And *AApSup 43*,209, λ And *ApJ 227*, 870, ζ And *PASP 92*,825*; R Aqr *ApJ 237*,506,840, *Nature 284*,148; AE Aqr *ApJ 234*,978, *MN 191*,559; U Aql *PASP 91*,840, V603 Aql *ApJ 234*,978; V805 Aql *ApJ 244*,541*, V822 Aql *PASP 93*,318, η Aql *ApJ 238*,L87; TT Ari *BAAS 12*,855; UX Ari *ApJ 239*,911, *241*,759, *AJ 85*,1086, T Aur *MN 192*,127*, AR Aur *PASJ 31*,821; α Aur *ApJ 241*,279; ε Aur *AAp 69*,23, 76,365, *MSAI 50*,201; ζ Aur *PASP 92*,790, *BAAS, 12*,851, *Nature 286*,580; TZ Boo *MittAG 45*,49; 44i Boo *BAAS 11*,722, Z Cam *IAU Coll 53*,499, *ApJ 236*,839; SZ Cam *BAC 31*,321, SY Cnc *Pis AZh 5*,452; WY Cnc *IBVS* 1484; Y Cnc *Pis Azh 5*,452, AH Cnc *MN 186*,729*, 45 Cnc *AJ 86*,271*, RSCVn *PASP 92*,675; TX CVn *AAp 88*,141*; UW CMa *MittAG 45*,52, *IAU Symp 88*,195, *IBVS* 1762, EZ CMa *ApJ 239*,607, α CMa *ApJ 232*,L189; YZ CMi *BAAS 11*,629, *12*,500,527,*ApJ 231*,L77, β Cap *ApJ 228*,497*, ζ Cap *ApJ 239*,L79, OY Car *AAp 85*,362*, *MN 194*,17P*, QZ Car *ApJ 231*,742*,239,L79, θ Car *PASP 91*,442*, RX Cas and SX Cas *BAAS 13*,523; RZ Cas *AApSup 38*,155*; HT Cas *AAp 76*,365, *ApJ 245*,1035*; BV Cen *IAU Colloq 53*,145, *ApJ 235*,945*; V346 Cen *PASP 90*,728*; V436 Cen *MittAG, 50*,28; U Cep *ApJ 233*, 906, *244*,546*, *MN 186*,391, *MittAG 45*,177, *IAU Symp 88*,237; VV Cep *BAAS 10*,620, *MSAI 50*,207, *IAU Symp 88*,549, *PASJap 33*,177; CQ Cep *IAU Symp 88*,177*, CX Cep *ApJ 244*,169*, UV Cet *BAAS 11*,629; Z Cha *MittAG 45*,158, *Obs 99*,186; 26 Com *JApA(Ind) 2*,115*, L CrB *MN 191*,521*, U CrB *Publ DAO 15*,419*; BI Cru *PASP 92*,479; α^1 Cru *MN 191*,217*; SS Cyg *ApJ 234*,997, *235*,163, *240*,597*, *AJ 84*,655, *IAU Colloq 53*,489*, SW Cyg *AA 29*,653; CG Cyg *AJ 84*,1218; CH Cyg *IAU Coll 53*,459, *PASJ 31*,307*; *ApJ 242*,188, *AAp 84*,366, *MSAI 50*,207; CI Cyg *Izv Krym 59*,133, *IBVS* 1759,1945, *AAp 93*,1, *Rap Int Frascati* No. 19, V382 Cyg *PASP 91*,474; V389 Cyg *MittAG 45*,53; V444 Cyg *Pis AZh 5*,398, V1073 Cyg *IBVS* 1579, V1329 Cyg *IBVS* 1525*, *BAC 30*,308, *ApSpSci 75*,237; V1341 Cyg (=Cyg X2) *ApJ 231*,539*, *BAAS 10*,607, *PASP 92*,147*, V1357 Cyg (=Cyg X1) *AJ 83*,962, *ApJ, 226*, 976, *PASP 91*,796; V1500 Cyg *ApJ Sup 38*,89, *IAU Coll 53*,522, *ApJ 230*,162, *Publ DAO 15*,73, *PASP 91*,446, *ApJ 236*,847, *237*,529; V1668 Cyg *AAp 85*,L4, *Pis AZh 6*,486; 31 and 32 Cyg *IAU Symp 88*,555; 47 Cyg *AJ 86*,271*; 57 Cyg *MN 189*,551*, β^1 Cyg *PASP 93*,323; HR Del *Nauch Inf* No. 42,21, *Pis AZh 5*,537, *PASP 91*,661,*92*,458, *ApJ 232*,176*, *BAC 30*, 129, *IBVS* 1811, *AA 29*,681, *ApSpSc 76*,149; δ Del *BAAS 11*,728; AG Dra *MN 195*,733, BY Dra *ApJ 234*,958*, *240*,567, *PASP 92*,548; DE Dra *MVS 8*,105, 40 Eri B *AJ 85*,1255, U Gem *BAAS 11*, 629, *PASP 91*,59, *AJ 84*,562, *ApJ 246*,215*, YY Gem *PASJap 32*,451; DN Gem *IBVS* 1711, IR Gem *Pis AZh 5*, 452, γ Gem *BAAS 10*,631*, AM Her *BAAS 10*,607, *ApJ 230*,502, *245*,1043*, *AZh 57*,65, *IAU Symp 88*,467, *PASP 93*,71; DQ Her *ApJ 224*,171, *226*,963, *232*, 500*, *233*,935, *238*,955*, *AA 30*,267*; HZ Her (=Her X1), *IAU Symp 88*,349, 88 Her *BAC, 29*,278, *IBVS* 1565, TW Hor *AAp Sup 36*,283*, RW Hya *BAAS 11*,730, *Nature 284*,148, *ApJ 240*,114, EX Hya *IAU Coll 53*,145, *AAp 87*,349*, VW Hyi *IAU Coll 53*,145, *ApJ 234*,1016, *ESO Mess* No. 16,15; WX Hyi *ESO Mess* No. 16,15; RT Lac *BAAS, 11*,651; AR Lac *IBVS*, 1880, *AJ 85*,1086, *86*,766; EW Lac *BAC 32*,56; 14 Lac *IBVS* 1886; 16 Lac *IBVS* 1552; 93 Leo *IBVS* 1833; 19 LMi *PASP 92*,98*; MV Lyr *ApJ 245*,644*; β Lyr *IBVS*, 1535; *ATs* 1009, 1036, *Izv Pulk* No. 197,89, *MSAI 50*,203, *IAU Symp 88*,271, *Pis AZh 6*,171,587,628; T Mon *ApJ 249*,1083, AU Mon 16 *Reunion Assoc. Arg. Astr.*; V616 Mon *MN 192*,709; U Oph *ApJ Sup 41*,1; RS Oph *PASP 91*,46; RZ Oph *ApJ 226*,937*, *AA 31*,25*; UU Oph *PASJ 32*, 445; V1054 Oph *BAAS 12*,500; η Ori *BAAS 12*,452; μ Ori B *PASP 92*,785*; σ Ori E *BAAS 10*,683; RV Peg *AJ 84*,655; AG Peg *IAU Symp 88*,535; *BAAS 11*,731; AV Peg *AJ 84*,1598; EE Peg *ApJ 244*,541*; II Peg *PASP 92*,333, *AJ 85*,1086, γ Peg *IBVS* 1598; X Per (=4U 0352 + 30) *Ap J, 227*,L21, *IAU Symp 88*,233,367, *BAAS 12*,500, *Izv. Krym. 61*,77; *AAp 94*,345; RY Per *AZh 56*,1012,1220; AG Per *ApJ Sup 41*,1; GK Per *IBVS* 1988, β Per *AA 29*,339,549; *AJ 86*,258; *IAU Symp 88*,223,225; ϕ Per *ApJ 233*,L73*, *IAU Symp 88*,199, *PASP 93*,297*, b Per *AA 29*,225*; AI Phe *AAp Sup 36*,453*, *MittAG 45*,49, RR Pic *ApJ 228*,482; δ Pic *PASP 92*,688; SZ Psc *AJ 85*,1086, *86*,771; 64 Psc *AAp Sup 35*,203*; RX Pup *MN 187*,813; VV Pup *IAU Coll 53*,330,334; *Nature 281*,47, *Proc ASA 3*,311, *MN 191*, 589; U Sge *ApJ 231*,495*; V Sge *IAU Coll 53*,448; WZ Sge *IAU Coll 53*,139,458,522, *ApJ 234*,182*, *236*,854*,L29, *237*,89*, *MN 191*,457, *AAP 87*,31, *IAU Symp 88*,447; FG Sge *AJ 85*,867; δ Sge *Proc 2 Eur IUE Conf* p.229; V356 Sgr *ApJ Sup 41*,1; V3885 Sgr *ApJ 234*, 1016, μ Sgr *IBVS* 1598, *BAAS 12*,869; υ Sgr *AAp 71*,310, *MSAI 50*,203, *IBVS* 1598, *IAU Symp 88*,271; U Sco *IBVS* 1738, *MN 195*,61, V453 Sco *MN 194*,537; V701 Sco *AAp 82*,225*, V818 Sco (=Sco X1) *BAAS 10*,607, *ApJ 226*,276, *237*,596, V861 Sco *BAAS 10*, 608, *ApJ*, *230*, 519*,231,171; β Sco A *PASP 91*,87*; *BAS Ind 7*,123, μ^1 Sco *16 Reunion Assoc Arg Astr;* RY Sct *IBVS* 1580, W Ser *BAAS 10*,609, UZ Ser *ApJ 234*,1016, CV Ser *ApJ 245*,195*, RW Tau *IAU Symp 88*,233; V471 Tau *IBVS* 1860,1951, V711 Tau *AJ 83*,1469ff, *85*,1086, *ApJ 224*,143, *239*,L121, *ApSpSc 74*,87, *PASP 91*,431, *IBVS* 1669; 33 Tau *JRASC 74*,365; λ Tau *ApJ Sup 41*,1, *IAU Symp 88*,293; RW Tri *AA 29*,469*; W UMa and AW UMa *MN 195*, 931*; XY UMa *IAU Symp 88*,423, *Proc 2 Eur IUE Conf* p.81; SU UMa *Pis AZh 5*,452; AN UMa *BAAS 10*,607, *ApJ 240*,871; 55 UMa *MN 195*,805*, γ^1 Vel *PASP 92*,819*; γ^2 Vel *ApJ 227*, 884, *228*,147, *238*,244*, α Vir *ApJ 227*,884, *228*,127; Nova Vul 1976 *AJ 85*,1232; Nova Vul 1979 *IBVS* 1835; HR913 *Obs 100*, 113*, HR 2024 *AJ 86*, 271*; HR 2072 *AJ 85*,858; HR 2081 *PASP 91*,824*; HR 2142 *PASP 90*,494, *IAU Symp 88*,293; HR 2923 *PASP 92*,713, HR 3337 *BAAS 10*,660; HR 3805 *Obs 101*,79*; HR 4249A *Obs 100*,161*; HR 4474 *MN 193*,957*; HR 4492 *AJ 85*,858; HR 4511 *ApJ 245*,201; HR 5161 *PASP 91*,521*; HR 6560, *AJ 86*,271*; HR 6626 *AAp 91*,112*; HR 6659 *Obs 100*,30*; HR 7084 *IAU Symp 88*, 293; HR 7922 *PASP 91*,685*; HR 8752 *AAp 70*,L53, *IBVS* 1492, *PASP 92*,497; HR 8891 *PASP 91*,685*; HD 2343 *Obs 99*,87*, HD 7308 *JRASC 74*,348*, HD 9974 *ApJ 244*,173; HD 11579 *Obs 99*,124*; HD 16219 *AAp Sup 44*,59*, HD 17212 *AJ 86*,271*; HD 17576 *Nature 275*,428; HD 22403 *AAp 74*,113*; HD 26874 and 28545 *AJ 86*,588*; HD 33917 *IBVS 1821*; HD 45088 *PASP 92*,218, *AJ 85*,294*; HD 49798 *AAp 70*,653; HD 50896 *PASP 91*,804; HD 77581 (=Vel X1) *IAU Symp 88*,359; *MN 195*,915; HD 90657 *IAU Symp 88*,177*; HD 92740 *ApJ 228*,206*, HD 94546 *IAU Symp 88*,177*; HD 96548 *AAp 91*,147*; HD 96953 *Obs 99*,145*; HD 97152 *ApJ 244*,528*; HD 106495 *Obs 101*,7*; HD 108078 *Obs 100*,1*; HD 108102 *ApJ 230*,L87; HD 126269/70 *AJ 86*,271; HD 131511 *JRASC 75*,56*; HD 137126 *Obs 99*,1*; HD 137569 *ApJ 241*, 1045*; HD 143313 *Obs 98*,257*; HD 152267 (=OAO 1653-40) *AAp 70*,L49, *ApJ 240*,161; HD 153919 (=4U 1700-37) *JRASC 73*,299, *ApJ 228*,L37, *231*,164, *240*,169; HD 155555 *AJ 85*, 858*; HD 155638 *BAAS 12*,855; HD 156731 *Obs 101*,51*; HD 159176 *MN 186*,13*; HD 164270 *AAp 96*,133*; HD 165590, *PASP 91*,304*; HD 166734 *BAAS 10*, 631; *ApJ 238*,184*; HD 170737 *Obs 100*,193*; HD 174237 *BAC 29*,288; HD 175742 *AAp Sup 38*,401*; HD 177624 *PDAO 15*, 411; HD 179558 *Obs 99*,36*; HD 186943 *ApJ 244*,157*; HD 192276 *JRASC 74*,342*; HD 192641 *IAU Symp 88*,187; HD 193077 *IAU Symp 88*,187; *ApJ 236*,526; HD 193857 *JRASC 72*,319*; HD 195987 *AApSup 42*,331; HD 197406 *AAp 86*,87*, *PASP 91*,827*; HD 199892 *PASP 90*,584*; HD 200775 *AAp 90*,290; HD 203631 *Obs 100*,73*; HD 211853 *ApJ 244*,157*; HD 214686 *PASP 90*,679*; HD 216533 *AAp 77*,263*; HD 218393 *BAAS 11*,648; HD 220007 *Obs 99*,198*; HD 224085 *PASP 91*,616; HDE 245770 (=A0535+26) *AZh 56*,450, *Pis AZh 6*,582; HDE 285970 *AJ 86*,588*; HDE 311884 *ApJ 242*,1050*; BD +61 1211 (=2A 1052+606) *BAAS 11*,783, *Nature*

282,691, *ApJ 234*,993*; BD +34 4216 *PASP 93*,364; BD +29 3805 *JRASC 73*,266*; BD +23 635 *AJ* 86,558*; BD -0 4234 *ApJ 239*,928; vB 162 and 182 *AJ 86*,588*; LSI 61 303 *PASP 91*, 661; LSS 1916 and 3371 *AAp 71*,214; LB 3459 (=HDE 269696) *IAU Coll 53*,255*, *MN 194*, 429*, *195*,165*; MR42 *IAU Symp 88*,177*; G61-29 *IAU Coll 53*,453; α_{50} 10 02 07 δ_{50} -40 31.9 *IBVS* 1532; SS433 *BAAS 11*,446,471,671,732,786,*12*,540, *ApJ 230*,L41, *233*,L63, *JRASC 73*,303; *S&T 58*,510, *AJ 84*,1037, *AAp 78*,L17, *84*,L4, *85*,14,94,251, *Pis AZh 6*, 623, *MN 193*,135; Step 153519 *IBVS* 1720; Wolf 424 *BAAS 12*,500; Wray 977 (=4U 1223-62) *AAp 76*,245, *MN 191*,547; ω Cen V78 *AJ 84*,1216*; M5 V101 *BAAS 13*,513, 7 58.8 - 32 39 *PASP 91*,800; ADS 14893 *BAAS 13*,569*; Aql X-1 *BAAS 10*,509; *S&T 59*,188, *ApJ 237*,154; Cen X-3 *ApJ 227*,1079*, *AAp 90*,113; Cen X-4 *ApJ 241*,L161; Cyg X-3 *ApJ 226*,282; Ser X-1 *ApJ 238*,964; A1742-28 *MN 192*,709; 2A 0311-227 *ApJ 232*,L27, *243*,567*, *Nature 281*, 48, *AAp 86*,L10, *MN 195*,155; 2A 1822-371 *Nature 276*,247, *ApJ*, *241*,1148; 2S 0921-630 *Nature 276*,799, *BAAS 11*,721; 2S 1524-690 *Nature 276*,247; 4U 1658-48 *ApJ 232*,L33; 4U 2129 +47 *ApJ 233*,L57, *BAAS 11*,445; PSR 0820 +02 *ApJ 236*,L25*.

C. POLARIMETRIC STUDIES (A.M. Cherepaschuk)

The most important results are: discovery of variable optical polarization of SS433 by I.S. McLean and S. Tapia, *Nature 287*,703; detection by J.C. Kemp *et al.* of the polarization evidence for an extended secondary envelope with an eclipsing region for Cyg X-1, *ApJ 228*,L23; discovery by I.S. McLean of periodic variation in the linear polarization of WR star HD 50896, *ApJ 236*,L149; development of the theory of the polarization of the optical radiation of X-ray binary systems by N.G. Bochkarev *et al.*, *Astron J Letts* (USSR) *5*,185.

Other publications are: *IAU Symp* No 89; *ApJ 225*,599, *227*,197, *229*,652, *231*, L141, *232*,181,L107,248, *234*,L135, *246*,203; *AAp 79*,254, *87*,210, *91*,97,372; *ATs* Nos. 1032,1147; *Astron J (USSR) 57*,587, *58*,146; *Astron J Letts (USSR) 6*,344; *MN 194*,283; *Nature 285*,306; *Nauch Inf (USSR)* Nos. 45,50,87; *PASP 92*,338.

D. X-RAY OBSERVATIONS (Y. Kondo)

Two X-ray satellite observatories were in operation during the period between 1979 January and 1981 June. They were the second High Energy Astrophysical Observatory, known also as HEAO-2 or *Einstein*, and the *Hakucho*, a Japanese word corresponding to Swan or Cygnus. *Einstein* was developed and operated by a consortium of 4 US institutions, Harvard-Smithsonian Center for Astrophysics, Massachusetts Institute of Technology, Columbia University and Goddard Space Flight Center; R. Giacconi was the Principal Investigator for the project. *Hakucho* has been developed and operated by the Institute of Space and Aeronautical Research, University of Tokyo; M. Oda is its Principal Investigator. *Hakucho* has produced results of much astrophysical significance but the results of *Einstein* are probably more of immediate interest to Commission 42.

The consortium of the 4 institutions obtained a large number of observations with *Einstein* on various X-ray emitting close binaries, including "normal" close binaries (e.g., Algol), RS CVn stars, cataclysmic variables, W-R stars and "conventional" X-ray binaries involving compact objects. In addition to the consortium observations, a great deal of data was obtained in a popularly subscribed guest observer program. The targets observed with *Einstein* are contained in *A Listing of All Targets Observed by the Einstein Observatory*, which may be obtained by requesting it from Dr. F.D. Seward of the Center for Astrophysics.

The observed targets are classified into a number of subgroups but there is no single subgroup for close binaries. It is often unclear from the proposal titles whether they pertain to close binaries. In addition, the objects observed with *Einstein* are quite numerous. Therefore, no attempt will be made to list all close binaries observed with *Einstein*.

The following lists the names and the institutions of *Einstein* guest observers whose proposal titles appear to pertain to close binaries. For further information,

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one may either contact the individual guest observer or request the *Einstein* target list from Dr. Seward.

A. Fabian *et al.*, U. Cambridge (RS Cen, SY For, γ Gem, also colliding stellar winds); D. Gibson, New Mexico Tech. (HR1099, RT Lac, AR Lac); J. Cassinelli *et al.*, U. Wisconsin (W-R stars, AG Dra, Ae/Be stars); C. Anderson *et al.*, U. Wisconsin (sybiotic stars); Koch *et al.*, U. Pennsylvania (active close binaries); A. Cowley *et al.*, U. Michigan (symbiotic stars, 4U1145-61)); J. Hutchings, Dominion Astrophysical Obs. (binary O stars); A. Bunner *et al.*, Perkin-Elmer Corp. (SMC X-1); R. McCray, U. Colorado (Her X-1); G. Chincarini *et al.*, U. Oklahoma (AE Aqr); B. Haisch *et al.*, Lockheed Res. Lab. (UV Cet); P. Szkody, U. Washington (AM Her, VV Pup, AN UMa); C. Bowyer *et al.*, U. Cal. Berkeley (U Gem, Aql X-1, white dwarfs, RS CVn, chromosphere in a binary, Sco X-1, SS Cyg); J. Nelson *et al.*, U. Cal. Berkeley (Novae and Nova-like objects); J. Patterson, U. Texas (cataclysmic variables); A. Kruszewski, Warsaw U. (AM Her and related objects); R. Cruddace *et al.*, Naval Res. Lab. (W UMa stars); W. Hiltner *et al.*, U. Michigan (spectroscopic binaries); J. Greenhill *et al.*, U. Tasmania (AM-Her-like objects); P. Agrawal, Tata Inst. (flare stars); I. Mitrofanov, Ioffe Inst., USSR (AM-Her-type stars); P. Sanford, Mullard Space Sci. Lab. (V861 Sco); F. Cordova, Los Alamos Sci. Lab. (Cyg X-6, cataclysmic variables); K. Singh, Tata Inst. (single-line spectroscopic binaries); A. Michalitsianos *et al.*, Goddard Sp. Flt. Ctr. (RW Hya); G. McCluskey *et al.* (interacting close binaries); A. Young, San Diego State U. (evolved eclipsing binaries); A. Haisch *et al.*, Lockheed Res. Lab. (dMe flare stars); G. Riegler *et al.*, Jet Prop. Lab. (single-line spectroscopic binaries); A. Moffat, U. Montreal (single-line W-R binaries); E. Geyer *et al.*, U. Obs. Bonn (TZ Boo, XV Cam, XY UMa); T. Snow, U. Colorado (29 CMa); W. DeCampli, Cal. Tech. (PSR 0820+02); J. Rahe *et al.*, Remeis Obs. (W-R stars, V603 Aql); H. Johnson, Lockheed Res. Lab. (spectroscopic binaries); G. Wallerstein *et al.*, U. Washington (eruptive symbiotic stars); S. Mufson *et al.*, Indiana U. (KR-Aur-like objects); S. Pravdo *et al.*, Cal. Tech. (classical novae); T. Ayres, U. Colorado (α Boo).

E. RADIO OBSERVATIONS (D.M. Gibson)

At least three distinct classes of interacting binaries exhibit radio emission: 1) RS CVn and related stars, 2) evolved mass-loss systems with interacting winds or hot components which ionize a cool wind, and 3) systems with collapsed components and hot accretion disks (e.g. SS433 and the X-ray binaries). In addition, Gregory and Taylor have discovered the interesting object LSI + 61^o 303 (=GT 0236 + 610), a star with a BOIbe spectrum and a radio period of 26^d5. They and their colleagues (*AJ 84*,1030) have noted the object may be coincident with a known X-ray source and γ-ray burster. Maroschi and Treves (*MN 194*,1P) suggest the synchrotron emission may be due to interaction of a pulsar secondary with the wind from the primary.

The current working model for radio emission from RS CVn and related systems has been elaborated by Gibson and/or Hjellming in a number of reviews (*JRASC 73*, 271; in *IAU Symp 86*,208; in *IAU Symp 88*,209; in *IAU Symp 88*,31; *Highlights 5*,857; in *Solar Phenomena in Stars and Stellar Systems*, 545). The flares or outbursts are probably gyrosynchrotron in nature and arise in the corona of the system where $n_e \sim 10^{10} cm^{-3}$ and B>100 Gauss. Quiescent emission, similar to that discovered in M-dwarfs by Gary and Linsky (*ApJ* in press), which is thermal in nature and arises from hot coronae (T>10 K) made optically thick at radio wavelengths due to gyroresonance absorption ($\overline{B}>10^3$G) may be detectable for less active systems such as AR Lac. Ryle (*PASP 91*,699) has shown that it is unlikely that the energy source for the radio emission is mass transfer as suggested by Florkowski (in *IAU Symp 88*); but, as is shown by optical and X-ray astronomers as well, the activity is due to the fact that these convective-envelope stars rotate much more rapidly (due to tidal co-rotation) than they would if they were single.

A number of new observations of RS CVn's and related systems have been reported including the detection of RS CVn itself by Gibson and Newell (*IAUC* 3337). The bulk of the monitoring of these systems has been done at Algonquin Radio Observatory

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by Feldman and his colleagues (*IAUC* 3366,3368,3487,3591). Most significant are their observations of multiple outbursts in objects like HR 1099, UX Ari, AR Lac and SZ Pxc (*IAU Symp 88*,403) and HR 5110 (=BH CVn) (*BAAS 12*,508). Other observations have been made at Arecibo by Fix *et al.* (*AJ 85*,1238) and Turner *et al.*) *BAAS 12*,499) and at the VLA by Bowers and Kundu (*AJ 86*,569), Gibson *et al.* (*PASP 90*,751), Johnson and Cash (*SAO Spec Rep 389*), and Newell *et al.* (*Proc SWRCAA, V*,13).

In their review of radio observations of stars with mass-loss Kwok and Purton (*IAU Symp 83*,151) defined a class II thermal source to be of the AG Peg-type (M III + O). Binaries of this type can be identified not only via the radiative ionization of the cool star's wind which results in the characteristic $\nu^{0.6}$ spectrum - even if the hot companion is not seen in the case of R Aqr (Johnson, *ApJ 237*,840) - but also by non-symmetric or variable mass-loss now seen in high resolution VLA maps which may be due to a close companion. Examples of both of these mass-loss phenomena are given in papers by Bowers and Kundu (*AJ 84*,791), and Newell and Hjellming (*BAAS 12*,458).

Only in case of close binaries with compact components and accretion disks does mass-transfer become important to the radio emission process. Nicolson (*IAU Symp 88*,347) interprets the 16.6 day-radio flare periodicity of Cir X-1 as being due to mass transfer at periastron of an eccentric binary. Apparao and Chitre (*ApSpSc 68*, 509) envisage the radio emission from point X-ray sources (e.g. 2U1735-44) arises from plasma oscillations in the outer regions of accretion disks at the impact point of the stream. Hjellming and Ewald (*ApJ 246*,L137) have detected a Sco X-1-like triple associated with the 1978 November 19 X-ray burster. No optical identification has been made as yet, but the radio appearance suggests it can be considered as a member of this class.

Perhaps the most interesting object in astronomy during the interval 1979-1981 was SS433, and radio astronomers have been instrumental in defining its unique nature. The underlying energy source for the radio, optical, and X-ray phenomena is a precessing accretion disk from which is directed a twin synchrotron-emitting jet with the following properties: inclination of jet precession axis $\sim 80^{\circ}$, position angle of precession axis $\sim 100^{\circ}$, misalignment of jet axis with precession axis $\sim 20^{\circ}$, velocity of ejected material $\sim 0.26c$, distance to SS433 ~ 5.5 kpc, and the jets rotate clockwise with eastern jet nearer (Hjellming and Johnston, *ApJ 246*,L141). A number of authors have contributed to studies of the radio structure using VLBI (Geldzahler *et al.*, *AA 98*,205; Schilizzi *et al.*, *AA 79*,6) and interferometric (Gilmore *et al.*, *AJ 86*,864; Hjellming and Johnston, *Nature 282*,483) techniques. Studies of its factor of ten radio variability were done by Heeschan and Hammond (*ApJ 235*,L129), Johnson *et al.* (*AJ 86*,1377) and Neizestnyi *et al.* (*Pis AZh 6*, 700). Radio spectra were measured by Ciatti *et al.* (*AA 95*,177), Cohen and Drake (*AA 89*,L6), and Seaquest *et al.* (*ApJ 241*, L77) and polarizations were measured by Aller *et al.* (*IAUC* 3376).

5. Physical Data

A. ABSOLUTE DIMENSIONS (T.Herczeg)

Current knowledge of stellar masses and radii, the most reliable information based on the study of binary orbits, is summarized by Popper, *Ann Rev AAp 18*,115. A list of absolute dimensions, luminosities and distances of 48 eclipsing systems is presented by Lacy (*ApJ 228*,817). Recent determinations (or re-evaluations) of masses and radii (1979-June 1981) based preferably on complete sets of photometric and spectroscopic elements, are compiled in Table 5.

Preliminary values of the masses and radii are frequently obtained under various plausible assumptions. Hall and Neff (*AA 29*,641) computed absolute dimensions for 32 sd-d and R CMa type binaries, assuming that the hotter components obey the mass-luminosity relation and the cooler stars fill their Roche lobes. In many cases the photometric mass ratio was applied to deal with systems with single line spectrum for instance, Cester *et al.*, *AAp Sup 39*,265 (8 systems); Wilson and Rafert, *AAp Sup 42*,195 (6 systems)). 40 Eri B was the subject of a detailed study and a new value of the relativistic redshift has been derived yielding $0.013R_{\odot}$ for the radius of the white dwarf (Wegner, *AJ 85*,1255). In the case of systems with severely distorted light and radial velocity curves, such as old novae, dwarf novae and magnetic binaries, particular models have been constructed leading to approximate values (or at least limiting values) for the masses and radii: Ritter, *AAp 85*,362, Bailey and Ward, *MN 194*,17P, Vogt *et al.*, *AAp 94*,L29 (OY Car) and Ritter, *AAp 86*, 204, Rayne and Whelan, *MN 196*,73 (Z Cha), also Paczynski and Dearborn, *MN 190*,295 (LB 3459), Schneider and Young, *ApJ 240*,871 (VV Pup, AN UMa).

Table 5. Absolute dimensions

V805 Agl *ApJ 244*,541; V535 Ara *AAp Sup 36*,278; V539 Ara *AAp Sup 36*,45, *AAp Sup 39*, 255; SX Aur *ApJ 228*,828; BF Aur *AJ 84*,326; β Aur *AAp 77*,214; SZ Cam *BAC 31*,321; AS Cam *AAp Sup 39*,255; TV Cas *Trudy Kasan Gorod.* AO 42-43; U Cep *ApJ 244*,546; TV Cet *AAp 72*,356; XY Cet *ApSpSci 71*,385; RS Cha *AAp 83*, 339; V380 Cyg *ApSpSci 71*,385; Y Cyg *AAp Sup 39*,255; MY Cyg *AAp Sup 39* 255; WW Dra *AAp Sup 39*,73; V624 Her *AAp Sup 39*,255; TT Hya *ApSpSci 67*,205; TZ Men *AAp 94*,204; AO Mon *AAp Sup 39*,255; V451 Oph *AAp Sup 39*,255; EE Peg *ApJ 244*,541; ϕ Per *PASP 93*,297; V Pup *AJ 84*,236; TX Pyx *AAp 101*,7; U Sge *ApJ 231*,495; V701 Sco *AAp 82*,225; μ^1 Sco *AJ 84*,236; BH Vir *AAp Sup 39*, 255.

B. PERIOD CHANGES (A.H. Batten)

In accordance with previous practice, we do not attempt to list all the systems for which period studies have been made. Algol-type systems, contact systems, cataclysmic variables and RS CVn systems have all attracted a considerable amount of attention and the necessary times of minima are being obtained. It is just as important, however, to obtain times of minima of systems whose periods are not yet known to change. This is underlined by Herczeg's discussion (*IAU Symp 88*,89) of period changes in detached systems. As a group, these systems have been believed not to suffer changes in period. Some members of the group do, however. In particular, the period change of RT And seems well established (Bakos and Tremko *IAU Coll 59* in press) although some uncertainty remains whether or not this is strictly a detached system.

Discussions of period changes in *IAU Symp 88* also concern RS CVn systems (Hall *et al.*, p.383) and contact systems (Havnes p. 521). Earlier, Kreiner and Ziokowski (*AA 28*,497) published a valuable survey of period changes in Algol-type systems. There is a growing realization that not all variations in times of minima can be correctly ascribed to changes of orbital period. Distortions of the light curve may affect the time determined for minimum light. This point is made in some of the above discussions and also by Tremko and Bakos (*Contr. Skalnate Pleso 9*, 163) and Batten (in *Photometric and Spectrosopic Binary Systems* ed. Carling and Kopal, Reidel p. 465) from studies of the period of U Cep. An important study of this latter system has been published by Olson et al. (*PASP 93*,464). The latest observations are not easily reconciled with the theory of period changes proposed by Biermann and Hall some years ago.

An interesting recent result is the claim by Kviz and Murray (*IBVS* 1864) that the secular decrease in the period of SV Cen has stopped. Even if it should not eventually be confirmed, this result reminds us of the danger of extrapolating 10^4 or 10^5 years "secular" changes established for at most two centuries.

C. APSIDAL MOTION (A.H. Batten)

Papaloizou and Pringle (*MN 193*,603) have studied the theory of apsidal motion taking into account the possibility of resonance between stellar oscillations and the orbital motion. They apply their results to a system resembling Vel X-1, but point out that these should be considered in *any* system showing observable apsidal motion. Monet has discussed the detectability of apsidal motion from spectroscopic observations alone (*PASP 91*,218) and has applied his methods to several systems

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(*ApJ 237*,513) comparing those showing apsidal motion with Stothers's models. He finds that either the models are too centrally condensed for their effective temperatures, or the computed radii are too small. Warner (*AA 28*,303) has discussed apsidal motion in cataclysmic binaries, taking account of the effects of the accretion disk. Some specific systems have been studied. Martynov and Khalullin (*ApSpSc 71*, 147) find the relativistic advance in DI Her to be too small by at least a factor of three. Kreiner and Tremko (*BAC 31*,343) dispute the previously claimed evidence for apsidal motion in TX UMa. Peterson *et al.* (*PASP 91*,87) adduce evidence for apsidal motion of β ScoA, while Giménez and Costa (*PASP 92*,782) have revised slightly downwards the ratio U/P for Y Cyg. Scarfe reports observations of DR Vul, YY Sgr, V523 Sgr and V346 Cen. Eclipses of DR Vul are departing from O'Connell's ephemeris and the existing ephemeris for eclipses of V346 Cen appears to be incorrect.

D. PROXIMITY EFFECTS AND LIMB-DARKENING (M. Kitamura)

Over the past three years, several important contributions were published upon the theory of tidal effects in close binary systems. Bochkarev *et al.* (*AZh* 56,16) calculated the ellipsoidal light variation caused by the tidally distorted component with a standard model atmosphere. The shape of the components of close binaries with elliptical orbits of small eccentricity was studied in detail by Urche (*BAC 29*,361) with the approximation of ellipsoidal configuration and he calculated the effect of shape variation and the surface temperature variation on the light curve. The effect of the second-order terms in tidal distortion was also discussed by Mohan and Singh (*ApSpSc 60*,423) for small oscillations of the tidally distorted components with the use of the Roche coordinates. The importance of tidal circulation of gases in close and contact binaries was also pointed out by Smith (*Obs 98*,207). The correlation between the intensity of Ca-K emission lines and the tidal effect was studied for G and K-type binary giants by Glebocki and Stawikowski (*AA 29*,505). Rafert and Twigg (*MN 193*,79) determined the gravity darkening exponent and bolometric albedo for close binaries from their multi-colour photoelectric light curves.

The reflection effect was discussed by Budding and Ardabilli (*ApSpSc 59*,19) for its formulation with σ-integrals. Dolginov and Fedorenko (*AZh 55*,1198) studied photospheric circulation currents in the inhomogeneously illuminated component and showed that the heating of the stellar surface causes no convection, provided that the photosphere was primarily radiative.

The linear limb-darkening coefficients in BV of the components of eclipsing binaries were compared in detail with the corresponding theoretical values currently accepted by Twigg and Rafert (*MN 193*,775). The limb-darkening law was also discussed by Lavrov (*Trudy Kazan 45*,40).

E. ATMOSPHERIC ABUNDANCES (M. Kitamura)

Considerable efforts have been directed to detect the spectra of secondary subgiant components in semi-detached close binary systems. The chemical composition of these secondaries is one of the most important factors for understanding their structure and evolution. Tomkin and Lambert (*ApJ 222*,L119) detected the NaD lines of Algol B by Reticon observation, and Kondo and Okazaki (*IAU Symp 88*,221) further determined precise sodium abundances of Algol A and B. The red and near-infrared spectra of secondary components of other Algol-type eclipsing binaries were also observed with the Reticon by Tomkin (*IAU Symp 88*,53) for study of their chemical abundances.

The decrease of the H abundance in the mass-losing components in Algol-type binaries was theoretically studied by Packet (*IAU Symp 88*,211) in connection with central H burning. The CNO abundances and their variations in WR binaries were discussed by Vanbeveren and Doom (*AAp 87*,77), and Sahade (*AAp 87*,L7) also suggested from IUE observations that the WR binary stars probably have a normal chemical composition, contrary to the general belief of their H-deficiency. Spectra of the unusual eclipsing binary system V453 Sco was carefully analysed for CNO abundances by Kane *et al.* (*MN 194*,537).

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Detailed statistical discussions were made by Kitamura and Kondo (*ApSpSc 56*, 341) for the Am components in spectroscopic binaries. The surface distribution of metallicity in the Am primary component of IW Per was studied by Kim (*ApSpSc 68*,355) from metallic-line intensities at various phases. Kitamura (*ApSpSc 68*,283) found, from a statistical study of the frequency distribution of the orbital inclinations, that the abundance anomalies of Ap components in spectroscopic binaries tend to concentrate towards the stellar polar region. This can explain the fact that no eclipsing system has been found in spectroscopic binaries with Ap spectra.

F. CIRCUMSTELLAR MATTER (M. Kitamura)

A critical review article, which is also very suggestive for future study, was presented by Kopal (*NATO Binary Symp* 1980) with four sections: dynamics of gas streams, physics of free gas, application to U Cep and conluding remarks. This review deserves perusal by researchers in this field. The Roche lobe overflow mechanism in semi-detached close binary systems was discussed by Budding (*NATO Binary Symp* 1980) guided by the work of Lubow and Shu. Sahade (*Coll. Univ. Sao Paulo* 1978) also gave a good review on the observed evidence for gaseous streams in close binary systems. Various useful suggestions for new observations and models for gaseous streams were given by Modisette and Kondo (*IAU Symp 88*,123).

Van Houten (*AAp 97*,46) discussed observational data of semi-detached close binaries and proposed a special model of gas streaming around the primary component. The location of gas streams in Algols was carefully discussed by Walter (*IAU Symp 88*,305) from investigation of good light curves. Mezzetti *et al.* (*AAp 83*,217) discussed mass loss and mass transfer in Algols from observational data with the purpose of checking current theoretical views. Tidally driven gaseous circulation in close and contact binaries was theoretically studied by Smith and Smith (*MN 134*, 583).

Some review on the circumstellar material in cataclysmic binaries was given by Smak (*IAU Symp 88*,443). The problem of rotating gaseous disks in close binaries was discussed hydrodynamically by Kitamura (*IAU Asian-Pacific Meeting* 1981) with application to the determination of dimension of an accretion disk in a cataclysmic binary.

6. Structure and Models of Close Binaries

A. EARLY-TYPE SYSTEMS

Extensive reviews and collections of research papers on the topics of close binaries containing O-type and WR stars may be found in *IAU Symp* 83 (*Mass Loss and Evolution of O-Type Stars)*, *IAU Symp* 88 (Section IV) and in the forthcoming proceedings of *IAU Symp* 99 (Wolf-Rayet Stars: Observations, Physics and Evolution). Mass, angular momentum and energy transfer in close binaries has been reviewed by Shu and Lubow (*Ann Rev AAp 19*,277).

Most of the efforts in theory of high mass binaries have been directed at evolutionary changes.

The structure of high mass contact binaries, computed on the contact discontinuity hypothesis, was investigated by Lubow and Shu (*ApJ 229*,657). Models for $4M_\odot+2M_\odot$ and $8M_\odot+4M_\odot$ systems were presented.

The single-line WR star EZ CMa was observed by Firmani *et al.* (*ApJ 239*,607), who conclude that the companion is probably a neutron star of mass $1.3M_\odot$. The orbit was found to have a noticeable eccentricity. Isserstedt and Moffat (*AAp 96*,133) conclude that the WR star HD 164270 also probably has a neutron star companion. A general survey of WR stars for compact companions was made by Seggewiss (*MittAG No. 51* 123).

Hutchings and Dupree (*ApJ 240*,161) used IUE spectra to investigate the stellar wind from the BOI component of HD 152667, which produces multi-component absorption lines. Kondo *et al.* (*PASP 92*,688), also from IUE observations, find a stellar wind with velocities $\sim$700 km s^{-1} from the B-type close binary δ Pic. Phase correlated P Cyg profiles were found in the CIII lines of UW CMa (Dreschel *et al. AAp 94*,285). McCluskey and Kondo (*ApJ 246*,464) similarly find P Cyg profiles and a stellar wind of $\sim 5 \times 10^{-6}$ $M_\odot$ yr^{-1} at 1880 km s^{-1} in AO Cas.

B. ALGOLS AND RELATED SYSTEMS (R. Hilditch)

Popper (*Ann Rev AAp 18*,115) and Tomkin (*IAU Symp 88*,53; *ApJ 231*,495) have made substantial contributions to the subject in determining directly the masses of the cool secondary components in 15 systems and further observations are currently in progress. At long last, it has been unequivocally established that the classical Algol systems are indeed semi-detached and that the current primary components behave an normal main sequence stars of solar-type composition despite their being the consequence of extensive mass transfer. Both components of Algol (Kondo and Okasaki *IAU Symp 88*,221) and U Cep B (Lambert *et al. MN 186*,391) are found to have normal population I compositions. As Packet (*IAU Symp 88*,211) has very clearly emphasised, an efficient mixing mechanism is required to destroy any abundance anomalies generated by the transfer process.

Okasaki (*PASJ 32*,445) demostrated that UU Oph is a normal Algol type system rather than the 'R CMa' class. Cester, Mezzetti, Guiricin and Mardirossian (*AAp Sup 36*,273, *37*,513, *39*,235, *39*,265, *39*,273, *40*,57) and Hall and Neff (*AA 29*,641) have reinvestigated many sd and sd-d systems. Most of the sd-d classifications (R CMa's) now seem to be sd systems whilst previous sd classifications are confirmed. Amongst the early type Algol systems, Chochol (*BAC 31*,321) demonstrated that SZ Cam is a semidetached system and Schneider *et al.* (*AJ 84*,236) reinvestigated the published light curves of BF Aur, μ'Sco and V Pup to confirm their sd nature. UV (Eaton *AA 28*,601) and BVR light curves (Provoost *AAp 81*,17) of μ Her both resulted in sd configurations and the primary component was found to be intrinsically variable in uv light.

Algol continues to be studied intensively at all wavelengths using all techniques. A comprehensive review of the geometry and dynamics of the system has been presented by Soderhjelm (*AAp 89*,100) whilst speckle interferometry studying the AB and AB-C orbits has been carried out by McAlistair and DeGioia (*ApJ 228*,493) and Bonneau (*AAp 80*,L11). New optical polarimetry obtained by Kemp *et al.*, (*Ap J 243*, 557) suggests that the orbits may be either coplanar or almost normal to each other, the result depending rather sensitively on the input polarimetric model. Separately, the polarisation data indicare transverse flattening of the secondary component's Roche lobe or the presence of an optically thick flattened gas cloud near L1. From Copernicus observations of the MgII 2800 feature, Cugier (*AA 29*,549) concluded that the rotation axis of Algol A is not perpendicular to the orbital plane of the AB system, whilst Chen *et al.* (*AJ 86*,258) interpreted their *k* line observations in terms of a nonuniform circumstellar envelope.

By far the most popular activity in the past triennium has been studies of the mass transfer and mass loss events. Amongst general surveys, Peters (*IAU Symp 88*, 287) has shown that the Hα emission is present in nearly all systems with P>6 days and that accretion disks extend out to 90% of the primary's Roche lobe. For P<6 days emission lines are transient phenomena lasting only a few orbital cycles. These conclusions are further supported by Popper (*IAU Symp 88*,203) who states that the primary components' radial velocity curves may well be seriously distorted for P>6 days but quite symmetric for P<6 days. Kulkarni and Abhyankar (*ApSpSc 67*,205; *J ApA 2*) report photometric observations of TT Hya, one of the longer period systems specifically noted by Popper for radial velocity complications. They conclude that the secondary component does *not* fill its Roche lobe and may still be in a pre-main sequence phase whilst the primary has an asymmetric circumstellar envelope. Dorren and co-workers (*IAU Symp 88*,59) have considerably extended their data base of Hα and Hβ photometry of interacting binaries including many Algol types. Mezzetti *et al.* (*AAp 83*,217) compared various theoretical models of mass loss and mass transfer against the observed properties of 55 Algol systems and concluded that case A predominated if M (total)>$10M_\odot$, case B predominated if M (total)<$6M_\odot$ whilst in the intermediate range A,B or AB seemed to be possible. Kreiner *et al.* (*AA 28*,497) reached similar conclusions from studies of period changes in 18 systems. Typical mass transfer rates required to explain the period changes seemed ro be $\sim10^{-7}$ to 10^{-6} $M_\odot yr^{-1}$ (U Cep; RX Cas (Kriz *et al. BAC 31*,284); TV Cas (Chaubey *ApSpSc 63*,247). Walter (*AAp 92*,86 and refs. therein) continues to apply his technique of short region rectification to the light curves of Algol systems in an attempt to remove effects of circumstellar matter and thereby deduce correct parameters for the systems.

Detailed studies of the gas stream effects in individual systems were mostly confinued to U Cep and Algol. Olson (*ApJ 237*,496; *241*,257) and Crawford and Olson (*PASP 91*,413) have continued intensive optical monitoring of U Cep to establish the presence of transient optically thick disks around the primary component which may extend out to 1.5R (pr) and be quite extensive perpendicular to the orbital plane. Piirola's polarimetric observations (*IAU Symp 88*,249) also indicated optically thick material around the primary in the form of an extended disk and a spherical envelope. The IUE satellite has been used by Kondo *et al.* (*ApJ 247*,202) some years after the major outburst on U Cep (1974/5) to study extensive circumstellar material manifested by resonance lines of Fe II and Mg II in the mid-uv. Their results show that the gas stream leaves the secondary, circuits around the primary about 270° and then leaves the system. Some additional source of energy other than gravitational potential energy is required to effect this mass loss. In the far uv spectrum, resonance lines of Si IV and C IV are present with strengths comparable to that in early B stars suggesting that a hot 'pseudophotosphere' is created by infalling matter from the gas stream on the surface of the B star.

A similar picture for mass loss from Algol is indicated by the radio and X-ray observations discussed by Florkowski (*IAU Symp 88*,229) who notes that the interception of the stream leaving the system with the surrounding diffuse cloud could produce the observed radio flares in Algol. Bolton and Zubrod (*IAU Symp. 88*,225) reported extensive monitoring of the Hα emission profile in Algol. The features are always associated with the primary component and the overall profile is very similar to that seen in Be stars.

Extensive use of the IUE satellite is being made by Plavec (*IAU Symp 88*,251; *IAU Coll 59*) with Dobias, Keyes, Weiland and Stone (*IAU Symp 98*) on the longer period interacting systems including β Lyr and W Ser. He identifies a group which display many similar characteristics of high mass transfer rates (10^{-5} $M_\odot yr^{-1}$) UV continua of higher colour temperature than observed in the optical region and many strong emission lines of highly ionised elements displaying P Cygni profiles. Interpretations of the data for various systems in terms of extensive accretion on to a non-degenerate star plus mass loss from the systems have been presented at recent AAS meetings.

IUE observations also feature strongly in the work on the ζ Aur systems 32 Cyg (Stencel *et al. ApJ 233*,621), VV Cep (Faraggiana *IAU Symp* 88, 549; Hagen *et al. ApJ 238*,203). In 32 Cyg all the resonance and other strong lines display P Cygni profiles and a mass loss rate of 4 x 10^{-7} $M_\odot yr^{-1}$ is derived. The B star seems to lie within the upper chromosphere of the K supergiant. In VV Cep Hagen *et al.*'s data indicate that the M supergiant's chromosphere is expanding. A year after eclipse, the spectra are still too complex (due to the interaction of the hot star's flux with the M star's chromosphere) to determine the spectral type of the hot companion. Optical photometry of these systems has been carried out by Hill *et al.* (*Pub DAO 15*,389) and on VV Cep by Saito *et al.* (*PASJ 32*,163). For VV Cep both groups report semi-regular variations in the light of the M supergiant whilst Hill *et al.* confirm the long term (15 yr) presence of a 25 day periodicity in the 3500 A light from the hot component.

The RS CVn stars have received considerable attention. At *IAU Symp* 88 and the *Joint Discussion on Close Binaries and Stellar Activity* (*Highlights 5*,839) several excellent reviews were presented of the observed properties at all wavelengths (X-ray to radio), theoretical models and unsolved problems of RS CVn's and the related BY Dra stars. These reviews together with several papers at the *Workshop on Cool Stars, Stellar Systems and the Sun* (*SAO Sp Rep 389*) provide an up to date picture of the RS CVn systems (apologies but lack of space precluded more detailed refs). Several of the problems highlighted by Hall in his baker's dozen have received some attention in the subsequent two years. Ramsey and Nations (*ApJ 239*, L121 and *AJ 85*,1086) studied HR 1099 and found a strengthening of the extremely temperature sensitive TiO band system near 8860A at phases where starspots were expected and deduced a minimum temperature difference of 1000°K between the spot and the surrounding photosphere. They also found a modulation of the Hα EW in HR 1099 in antiphase with the photometric distortion wave, a result already seen in UX Ari and CC Eri and expected from the star spot model - sufficient evidence to convince the devil's advocate? On the other hand the variations in the Ca II emission line strengths and profiles observed in RS CVn by Naftilan and Drake (*PASP 92*,675) and in AR Lac by Naftilan and Aikman (*AJ 86*,766) show no correlation with orbital phase or the migrating distortion wave and in AR Lac they display rapid (hourly) variations.

Optical photometric monitoring of RS CVn systems continues with obvious enthusiasm since 20 systems were investigated in the past triennium (section 4). It is noteworthy that long term studies (e.g. RS CVn Catalano *et al.*, *IAU Symp 88*,405) reap rewards in furthering our understanding of the photometric irregularities. It is unfortunate that, as yet, only Antonopoulou and Williams *ApSpSc 67*,496) seem to have used IR photometry to investigate the light variations due to spots.

It seems to be well established now that rapid rotation (>10 kms^{-1}) is the necessary and sufficient condition for the development of extreme surface activity in BY Dra and RS CVn stars (Bopp, *Highlights 5*,847, Bopp and Stencel *ApJ 247*,L131). Walter *et al.*, (*ApJ 236*,212 and *SAO Sp Rep 389*,35) conclude that a coronal loop model can successfully explain the X-ray observations of RS CVn systems; the differences between solar activity and RS CVn activity may be merely a matter of scale. In the UV region, Simon and Linsky (*ApJ 241*,759) used IUE to study HR 1099 and UK Ari and show that the strong emission lines originate in the K star chromosphere.

C. W URSA MAJORIS SYSTEMS (S.M. Rucinski)

In contrast with previous reporting periods, no basically new theory for the structure and evolution of W UMa-type systems has been developed during the past triennium but a number of studies were devoted to improvements and polishing of the already existing ideas.

In spite of considerable efforts relatively little progress has been achieved in resolving the dilemma of contrasting theories: the DSC (contact discontinuity) and the TRO (thermal relaxation oscillation) theories (cf. previous Comm. 42 report, *IAU Trans. 17A* Pt.2). The DSC theory received considerable criticism on physical grounds; the new (Papaloizou and Pringle, *MN 189*,5P; Smith *et al.*, *MN 190*,177) and old criticisms have been addressed by Shu *et al.* (*ApJ 239*,937). Moreover, Shu (*IAU Symp.* 88,477) thinks that the theories are not contradictory but rather complementary. He points out that the TRO cycles (actually around the DSC equilibrium models) can be demonstrated to exist only when the temperature inversion layer quickly disappears leading to the heating of the interior of the secondary and to the equalization of entropies between components. The DSC theory rests entirely on the severely attacked assumption that the inversion layer can be maintained for nuclear time scales. Apparently, not much hope is expected from further theoretical considerations so that this once rather hot debate has recently somewhat calmed.

The effort by Lucy and Wilson (*ApJ 231*,502) to resolve the above disagreement by using observations is inconclusive but the authors collected many facts which they interpret in favour of the TRO theory. In particular they claim to have identified four systems in the broken-contact phase of the TRO; they call this subtype the B-type W UMa systems. Proportion of four out of about fifty systems with *pe* light curves would be in agreement with the unequal duration of branches in the TRO cycles which are determined by thermal time scales of both components.

An extensive summary and rediscussion of the available observational data by Mochnacki (*ApJ 245*,650) indicated that primaries of contact binaries seem to resemble single stars of the same mass once luminosity transfer is corrected for. He showed that the B-type systems of Lucy and Wilson are evolved systems with peculiarities rather than the broken-contact configurations in the TRO cycles. He notes that the DSC theory also does not correctly describe the contact behaviour. He confirms an earlier result by Wilson (*ApJ 224*,885) that the A-subtype systems are the low mean density and low mass-ratio evolved systems which either have always been in contact or evolved into it from detached configurations; the W-subtype have components similar to the MS stars and might have originated as contact binaries with mass-ratios not very far from unity. The most interesting is a small group of evolved (low mean density) systems with almost identical components like OO Agl which *must* have evolved from detached systems probably by the mechanism of the orbital angular momentum loss due to the magnetic wind in tidally locked convective stars. This (partial) alternative to the DSC and TRO theories which has been vigorously advocated by van't Veer (*AAp 80*,287; *98*,213), Vilhu and Rahunen (*IAU Symp*. 88,491), and Vilhu (*ApSpSc 78*,401) has recently received considerable observational support from the satellite ultraviolet (the IUE) and X-ray (the Einstein) observations indicating strong chromospheric and coronal activity of the W UMa-type systems. A convenient summary was presented by Dupree *Solar Phenomena in Stars and Stellar Systems*, Reidel 1981, p.407). The main results, which still require further work because of the small sample (5-10 systems), are as follows:
The chromospheric and transition region lines show a general progression of increasing enhancement with increasing temperature of line formation much like that found for solar active regions or other active dwarfs. (This progession has been confirmed for W UMa by Rucinski *et al.* (in prep.) who obtained further IUE data for fainter systems). But according to Dupree, the correlation of the line fluxes and rotational velocities is not very strong. Also, the X-ray emission (Carroll *et al.*, *ApJ 235*, L77; Cruddace and Dupree, in prep.) does not follow the relation $L_x/L_{bol} \sim \Omega$ found for other active stars by Walter and Bowyer (*ApJ 245*,671,677) but is much steeper suggesting an Ω^3 dependence with a clear dichotomy between the A and W subtypes (W being again more active). Vilhu (1981, Santa Cruz Workshop) thinks this steepness might result from the existence of the period-colour dependence. The interrelation of coronal and transition region emissions for individual systems is not clear at all; as pointed by Dupree, for ε CrA, the variations in both emissions might be anticorrelated, so the behaviour is contrary to that found in solar active regions. Rucinski (*2nd UCL Coll*. London, Sept. 1981) points out that the angular momentum loss for contact binaries might be self-restricting (increase of the velocity of escape) possibly leading to more closed-loop geometries of magnetic field lines.

The surface magnetic fields and concentration of spots on the more massive component might be the explanation for the W-subtype pecularities, as evidenced on the basis of the ANS satellite photometry by Eaton *et al.* (*ApJ 239*,919); cf. also the colour variations data for SW Lac by Stepien (*AA 30*,315). This concentration, on the the other hand, confronts us with an unexplained phenomenon which might have a direct relation to the internal structure of contact configuration. Support of the ANS results is expected from the application of the spectrum deconvolution methods (Anderson *et al.* *IAU Symp* 88,485; Anderson and Shu *APJ Sup 40*,667; McLean, *MN 195*, 931) which will permit reconstruction of the surface brightness distribution over contact configurations. The new IUE data (Rucinski *et al.* in prep.) have too low accuracy to improve the ANS result but they confirm freedom of the ANS photometry from any emission line problems.

The increased interest in novel observational techniques does not contradict the continuing usefulness of more traditional approaches, especially if directed at particularly useful systems. Two more systems in open clusters have been analysed: AH CnC in M 67 (Whelan *et al.*, *MN 186*,729) and V701 Sco in NGC 6383 (Andersen *et al.*, *AAp 82*,225). Of the field objects we will single out only TZ Boo (Hoffmann, *AAp Sup 40*,263, *IBVS* 1877) as perhaps crucial for understanding of the A-W subtypes dichotomy. The observational status for early-type contact binaries has been reviewed by Leung (*IAU Symp 88*,527) and by Wilson and Rafert (*ApSpSc* in press). The first application of the DDO photometry to the W UMa systems by Hilditch (*MN 196*,305) suggests practically no gravity darkening (the exponent β=0 in $T_e \sim g^\beta$) for convective contact systems, in marginal agreement with the aforementioned ANS result by Eaton *et al.* (β=0.03$\pm$0.01) but in disagreement with the more conventional result of β=0.07-0.09 by Rafert and Twigg (*MN 193*,79)

Finally, returning to the theory of stars in contact: The problem of the energy exchange, which even in the simplified versions remains very difficult has been addressed by Smith *et al.* (*IAU Symp. 88*,495; *MN* 194,583). The thermally driven analogue of the Eddington-Sweet circulation resulting from distortions seems to play no role in transporting the energy, contrary to the global circulation arising from the non-uniform heating of the base of the common envelope. A rather elaborate model of such a steady circulation has been computed by Robertson (*MN 192*,263). The efforts to study the stability and evolution of contact binaries using the formalism of response functions have been continued by Hazlehurst, Refsdal, Stabell and Höppner (*AAp, 84*,200; *93*,297; in press). They find that evolution can occur in either cyclic or non-cyclic modes, depending on the system parameters, mainly on the depth of convective zone. Webbink (*IAU Symp 88*,127) studied the stability of early-type contact binaries; he also considered the expected properties of very evolved, Pop. II contact systems (*ApJ 227*,178) and their relevance for searches of such objects in globular clusters. In a review paper on evolution of close binaries (*IAU Coll 53*,426), he thoroughly discussed possible interactions leading to emergence of contact configurations.

D. NOVAE AND RELATED STARS (J. Smak)

Proceedings of *IAU Symp. 88* and *IAU Coll. Nos 46* and *53* have been published and they contain, in particular, reviews on various aspects of cataclysmic variables (CV) by Warner (*IAU 46*,1; *IAU 53*,417), Robinson (*IAU 46*,77) and Webbink (*IAU 53*, 426). In another review Bath (*Proc R Soc A366*,357) compared optical and X-ray novae. There was a further increase in the number of observational and theoretical papers on CV's and only a small fraction can be quoted below (for complete references cf. *AAA*).

New spectroscopic observations resulted in a major improvement of basic model parameters for several CV's. Among them: U Gem (Wade, *ApJ 246*,215; Stover, *ApJ 248*,No.2), DQ Her (Young and Schneider, *ApJ 238*,955; Hutchings *et al.*, *ApJ 232*,500; Smak, *AA 30*,267), SS Cyg (Kiplinger, *AJ 84*,655; Cowley *et al.*, *ApJ 241*,269; Stover *et al.* *ApJ 240*,597; Walker, *ApJ 248*,256). Near-IR spectroscopy and IR photometry begun to supply information, primarily about the cool, secondary components (Young and Schneider, *ApJ 247*,960; Bailey *et al.* *MN 196*,121; Frank *et al.*, *MN 195*,227 and 505). Ritter (*ESO Mess.* No. 21) rediscussed the mass-radius relation for the secondaries and concluded that on average they do not deviate from the standard relation defined by MS stars (obvious exceptions are secondaries in longer period systems).

Extensive studies of Z Cha, the first CV showing eclipses of the hot spot and white dwarf, led to a detailed model of this system (Bailey, *MN 187*,645; Rayne and Whelan, *MN 196*,73; Vogt, *AAp* in press). Two other objects with hot spot and white dwarf eclipses are: OY Car (Vogt *et al.*, *AAp 94*,L29) and HT Cas (Patterson, *ApJ Sup 45*,No.3; Young *et al.* *ApJ* 245,1035) for which Patterson found that the disk expanded during an outburst and almost disappeared immediately afterwards. The 1978 outburst of WZ Sge was covered extensively in a broad spectral interval (Fabian *et al.*, *MN 191*,457; Friedjung, *AAp 99*,226; Crampton *et al.*, *ApJ 234*,182; Ortolani *et al.*, *AAp 87*,31; and many others). Its light curve showed periodicity with P by about 1 per cent longer than the orbital period (Bohusz and Udalski, *IBVS* 1583; Patterson *et al.*, *ApJ 248*, in press) implying that WZ Sge is an SU UMa type dwarf nova. Individual members of the SU UMa subclass were studied in several papers and their group properties were discussed by Vogt (*AAp 88*,66) and Patterson (*AJ 84*,802). Recent suggestions concerning the origin of the superhumps range from an elliptical orbit leading to modulated mass transfer (Papaloizou and Pringle, *MN 189*,293) to an external ring proposed by Gilliland and Kemper (*ApJ 236*,854) for WZ Sge. Vogt *et al.* (*AAp 85*,106) found that the light curve of the 98 min binary EX Hya is modulated with P=67 min. The most likely explanation consists of a parametric excitation of a pulsation mode in the secondary component (Papaloizou and Pringle, *MN 190*,13P), leading to modulated mass transfer and to a variable intensity of the hot spot (Warner and McGraw, *MN 196*,59P).

In the AM Her group we note the discovery and extensive study of 2A0311-227 with P=81 min (Allen *et al.*, *MN 195*,155; Crampton *et al.*, *ApJ 243*,567; Patterson *et al.*, *ApJ 245*,618; Schneider and Young, *ApJ 238*,946; and many others). H2252-035, an optical and X-ray pulsar is a marginal member of AM Her group (Patterson and Price, *ApJ 243*,L83). Extensive optical and X-ray observations of AM Her in the high and low state were reported and discussed in many papers (Crosa *et al.*, *ApJ 247*,984; Szkody *et al.*, *ApJ 241*,1070; Young *et al.*, *ApJ 230*,502; *245*,1043; Latham *et al.*, *ApJ 246*,919; Hutchings *et al.*, *ApJ 247*,195; Tuohy *et al.*, *ApJ 245*,183; Schmidt *et al.*, *ApJ 243*,L157). They give magnetic field of about 10^7G.

X-ray and UV observations provide now a wealth of information on the structure of disks and details of the accretion process (Cordova *et al.*, *ApJ 245*,609; *MN 190*, 87; Becker and Marshall, *ApJ 244*,L93; Fabiano *et al.*, *ApJ 243*,911; Bath *et al.*, *MN 190*,185; Szkody *ApJ 245*,577). In the case of dwarf novae there is increasing evidence in favour of no major accretion at minima with sudden accretion during outbursts. The same conclusion was reached on other grounds for U Gem by Paczynski and Schwarzenberg-Czerny (*AA 30*,127). Analysis of photometric data leads to a conclusion that the surface brightness of the disk in DQ Her increases toward the centre (Dmitrienko and Cherepaschuk, *AZh 57*,749) while an opposite is true for Z Cha (Smak, *AA 29*,309). Extensive model calculations for the continuum and line radiation from disks were reported by Herter *et al.* (*ApJ Sup 39*,513), Mayo *et al.* (*MN 193*,793), and Williams (*ApJ 235*,939). Theoretical studies of disks included: low pressure models by Paczyński and Rudak (*AA 30*,237), alpha-disk models with variable mass transfer by Bath and Pringle (*MN 194*,967), and the tidal torques in the outer regions of disks by Lin and Papaloizou (*MN 186*,799).

In the area of short-period oscillations Patterson (*ApJ 233*,L13; *234*,978; *241*, 235) reported and discussed strictly periodic light variations in nova V533Her, nova-like AE Aqr, and WZ Sge. This shows that such oscillations, first detected in DQ Her, can be present in any type of CV. It appears that a pulsar-type model, involving beamed radiation from a magnetic, rotating white dwarf, can best explain the high clock stability and also the phase shifts observed during eclipses in DQ Her and UX UMa (Alpar, *MN 189*,305; Chester, *ApJ 230*,167; Petterson, *ApJ 241*,247). Optical and X-ray studies of the 7-9 sec oscillations from SS Cyg (Horne and Gomer, *ApJ 237*,845; Hildebrandt *et al.*, *ApJ 243*,223; Cordova *et al.*, *ApJ 235*,163) locate their source on or near the surface of the white dwarf but are still unable to discriminate between the pulsational and rotational mechanism. Other studies of coherent oscillations from dwarf novae (Patterson, *ApJ Sup 45*, No. 3; Hildebrandt *et al.*, *ApJ 248*, 268) show that they are strictly periodic and sinusoidal and come from hot plasma. The quasi-periodic luminosity variations (Robinson and Nather, *ApJ Sup 39*,461) can be represented as a 2nd-order autoregressive process and must originate in the disk.

The only two helium CV's are G61-29 and AM CVn. Nather *et al.* (*ApJ 244*,269) found P=46 min for G61-29 and suggested that evolution of this type may be responsible for the production of all DB white dwarfs. Patterson *et al.* (*ApJ 232*,819) found that the 18-min period of AM CVn is rapidly increasing at a rate corresponding to the mass transfer of $3x10^{-7}$ $M_{\odot}$/yr.

Observational data for several recent novae have been analysed to give description of their expanding envelopes. Among new effects, the heating by X-rays was discussed by Ferland and Truran (*ApJ 244*,1022) to explain apparent over-abundances of helium and heavier elements in the expanding envelopes of many novae (Ferland and Truran, *ApJ 240*,602; Williams and Gallagher, *ApJ 228*,482; Gallagher *et al.*, *ApJ 237*, 55; Barlow *et al.*, *MN 195*,61). Ruggles and Bath (*AAp 80*,97) studied the structure of optically thick winds in novae. Shara *et al.* (*ApJ 239*,586) studied the effect of CNO abundance and envelope mass on the speed class of novae and Shara (*ApJ 243*,268 and 926) gave theoretical explanation for the minimum spread in the absolute magnitudes 15-18 days after maximum and for the absolute magnitude - decline rate relation among novae. This relation was also rediscussed by Duerbeck (*PASP 93*,165).

E. X-RAY BINARIES (E.P.J. van den Heuvel)

Low-mass systems. Abundant evidence became available indicating that the type II (intermediate and old population) strong galactic X-ray sources ($L_x \gtrsim 10^{35}$ ergs/sec) are neutron stars in binaries with a low-mass companion. The neutron star character follows from the fact that many of these sources are X-ray bursters. The burst characteristics indicate (i) an average source size of about 7.5 km (van Paradijs, *Nature 274*,650), and (ii) that the bursts are helium-burning flashes on the surfaces of accreting neutron stars (references in the reviews by Lewin and Joss, *Space Sci Rev*, in press; Joss *Proc. 9th Texas Symp Relativ Astrophys; Annals N.Y. Acad. Sci. 336*,479). Further, from the location of 11 type II sources in globular clusters, an average source mass of $2M_{\odot}$ was derived (Grindlay, in *X-ray Astronomy, Proc. HEAD/AAS Meeting 1980*, ed. R. Giacconi), i.e. characteristic for a low-mass neutron star binary. The binary character of 9 type II sources has been established directly: (a) in four cases by the detection of a G-or K-dwarf absorption spectrum in a type II source during low X-ray intensity, and (b) in five more cases by the detection of regular X-ray or optical variability; these are the sources 4U 1916-05 (P=52 min.), 2A 1822-37 (5.57^h), 4U 2129+47 (5.2^h), 4U/MXB 1735-44, 4U/MXB 1636-53 (references: see review by J. van Paradijs, in: *Accretion-driven Stellar X-ray Sources*, W. Lewin and E.P.J. van den Heuvel, eds. Cambridge Univ. Press).

The X-ray binary with the shortest orbital period thus far detected (41 min.) is the 7-second X-ray pulsar 4U 1626-67 (Middleditch *et al.*, *ApJ 244*,1001); its companion must have a mass $\lesssim 0.1$ $M_{\odot}$. The low-mass system with the longest period is Cygnus X-2 (P = 9.8 days, Cowley *et al.*, *ApJ 231*,539) followed by 2S 0921+63 (P=8.9^d, Chevalier and Illovaisky, *AAp* in press). Important information on the dimensions of X-ray burst systems was obtained from simultaneous observations of optical and X-ray bursts. The time delays of 2 to 3 seconds and the intensities ($\sim 10^{-4}$ L_X) of the optical bursts show that these are reprocessed X-ray radiation from a disk with a radius of about one lightsecond (cf. Pederson *et al.*, *ApJ* in press; further references in abovementioned review by van Paradijs). (From the source 4U/MXB 1636-53 no less than 41 correlated bursts were observed up till mid-1981). The system Her X-1/Hz Her was studied further by Boynton and collaborators and by Kippenhahn and Thomas (*AAp* in press). In a detailed study Crosa and Boynton (*ApJ 235*,999) presented further evidence indicating that the 35-day optical and X-ray cycle are due to the precession of a tilted accretion disk that is most probably fed by a variable mass transfer rate. The low-mass systems 2A 1822-37 (5.57 h) and 4U 2129+47 (5.2h) are in many respects similar to Her X-1, and also show large regular optical modulations (amplitudes of 1^m and 1.5^m, respectively, in the blue; detailed references in van Paradjis' review, see above). For X-ray emission of cataclysmic variables and AM Her systems; see Smak (6D).

Massive X-ray Binaries. The B-emission X-ray binaries have become established as a major class of sources: with 12 known systems they have become the most abundant type of massive X-ray binary (references: see the review by Rappaport and van den Heuvel, *IAU Symp 98: Be Stars*, Reidel). In many cases they appear to be pulsating transients in which the Be star underfills its Roche lobe, and highly variable mass transfer takes place from the ring, shell or wind of the Be star. The most spectacular example is A 0538-66 in the LMC, which has a recurrence period of 16.65 days, during which its X-ray flux varies by more than a factor 10^4 (Charles *et al.*, *Space Sci Rev*, in press; Skinner, *ibid.*).

Well-determined doppler orbits are now available for 6 pulsating X-ray binaries; in 5 of these cases also the orbit of the companion is known and the masses of both components have been determined. The resulting neutron star masses are, within the error limits imposed by the observational uncertainties, consistent with the mass range 1.2 to 1.6 $M_\odot$, as predicted by stellar evolution theory (see the reviews by Rappaport and Joss, in *X-ray Astronomy* and in *Accretion driven Stellar X-ray Sources*. The most complete determination of an optical orbit was that of 4U 0900-40/HD 77581 (Zuiderwijk 1979, Ph.D. thesis, University of Amsterdam). (Further references in van Paradijs' review, see above). Further highlights were the study of high-energy features in the X-ray spectra of Her X-1 and 4U 0115+62 which - if interpreted as due to cyclotron radiation - indicate surface magnetic field strengths of 4.10^{12} and 2.10^{12} gauss, respectively (cf. Trümper, in *Accretion driven stellar X-ray sources*. So far, 20 pulsating binary X-ray sources have been detected, of which 18 are in massive systems.

Peculiar Systems. The 3.49 second pulsating source 1E 2259+586 and the system SS 433/A 1909+04 are both located inside large X-ray and radio shells, resembling SN remnants. The discovery of the moving balmer-line components in the spectrum of SS 433 by Margon *Ann. N.Y. Acad. Sci. 336*,350) indicates the presence of beams of gas ejected from the central star with a constant velocity of 0.265c, and uniformly describing a precession cone in 164 days (Milgrom, *AAp 76*,L3; Abell and Margon, *Nature 279*,701; detailed references in Margon, *Accretion-driven stellar X-ray sources*. The 13.1 day spectroscopic binary period was discovered by Crampton *et al.* (*ApJ 235*,L131); the He II 4686 velocity amplitude (Crampton and Hutchings, *ApJ* in press) indicates for the companion of the compact star a mass $\geqslant$ 11 $M_\odot$, which places SS 433 in the class of the massive X-ray binaries. The reality of the precessing beams has been confirmed by radio and X-ray observations (Schilizzi *et al. Nature 290*,318; Hjellming and Johnston, *Nature 290*,100). The simplest model for producing the beams appears to be that of a precessing supercritical accretion disk around a compact object (Katz, *ApJ 236*, L127; van den Heuvel *et al.*, *AAp 81*,L7). Optical indications for the presence of the disk follow from the photometry of Kemp *et al.*, *ApJ 238*,L133), and Cherepaschuk (*MN 194*,761).

Evidence for a precessing disk was also found from the 30.5 day flux modulation in the 1.4d period massive X-ray binary LMC X-4 (Lang, Levine *et al.*, *ApJ Lett* (in press)) which was subsequently found to be a 13.51 second X-ray pulsar.

Theory/Evolution. Advances in the theory of spin-up and spin-down of accreting magnetized neutron stars were made by Lamb and co-workers (references in the review by Lamb, *IAU Symp 95*; Wang *AAp* in press and Davies and Pringle, *MN 199*,599). (Up to date references in: Henrichs, *Accretion driven Stellar X-ray Sources*).

Reviews on the present ideas on mass-transfer mechanisms in X-ray binaries are given by Rappaport *et al.*, (*ApJ* in press), van den Heuvel (in: *X-ray Astronomy*). Reviews on the evolutionary history of binary X-ray sources were given by Tutukov (in *IAU Symp 93*, van den Heuvel (*ibid)*, and van den Heuvel (*Space Sci Rev* in press).

7. Statistical Investigations

Garmany (*IAU Symp 83*,261) has shown that about half of all O-type stars are binaries, two thirds of which are double-line systems. Moreover, a sample of 67 O stars, studied by Garmany *et al.*, (*ApJ 242*,1063) showed only 36 percent detected as binaries. The paucity of single-line and low amplitude systems indicates that mass ratios greater than 3 do not exist.

Vanbeveren and Conti (*AAp 88*,230) reconsidered the binary frequency of WR stars and concluded that earlier estimates were statistically biased. Many of those systems where no OB companion is detected may have a compact companion. However, there is evidence that some WR stars are single.

The distribution of mass ratios of double-lined binaries (Lucy and Ricco, *AJ 84*,401) suggests that many close binaries (P<25 days) are formed by a mechanism which prefers systems with identical components. Similar results are obtained by Tutukov and Yungelson (*IAU Symp 88*,15), who also conclude that selection effects allow the discovery of only about one third of all spectroscopic binaries, which suggests that almost all stars are binary.

The period distribution of close binaries was discussed by Mantegazza *et al.* (*IAU Symp 88*,23).

Wilson and Rafert (*ApSpSc 26*,23) investigated the frequency of an index denoting degree of contact in early-type binaries. Their results indicate continuity in frequency across marginal contact.

Rong (*AA Sin 20*,217) studied the statistical distribution of a system consisting of binary stars and concluded that the majority of single stars are not produced by dissociation of doubles, that at present in the Galaxy capture is more probable than dissociation, and that decreases in separation are more probable than increases.

8. Origin and Evolution of Close Binaries
(E.P.J. van den Heuvel)

Origins. Kraicheva *et al.*, *AZh 55*,1176, Tutukov (*IAU Symp 93*,137) and their collaborators, and Lucy and Ricco (*AJ 84*,401) have found that among unevolved spectroscopic binaries with $P \lesssim 25^d$ systems with mass ratios close to unity dominate. The same is true for the O-type spectroscopic binaries (Garmany and Conti, *IAU Symp 88*, 163). Among the wider binaries the distribution of the mass ratios q slowly increases towards the lower q values (Abt and Levy, *ApJ Sup 36*,241), which suggests different formation mechanisms for short-period and long-period systems. The peak near q=1 for short-period systems can be explained by fragmentation of a rotating collapsing cloud (Lucy, *IAU Symp 93*,75, additional references in: *IAU Symp 88* and in *IAU Symp 93)*.

Evolution. Non-conservative evolutionary scenarios are being developed in various parts of the world. The observation of evolved extremely close binaries (P of order of hours) with one degenerate component in young open clusters (Hyades), in the centre of at least 4 planetary nebulae, together with the enormous abundance of cataclysmic binaries in the galaxy shows that many binaries of moderate mass must evolve with extremely large losses of mass and orbital angular momentum as was first suggested by Ritter and Paczynski. Systematic investigation of the possible types of evolution of binaries (Webbink *IAU Coll 53*) together with the fact that over 2/3 of all stars are in binaries, indicates that over 40 percent of all stars will evolve through a common-envelope (CE) phase and terminate life in an extremely compact close binary. The common envelope (originally the envelope of the more massive component) is lost in the spiral-in process. Promising numerical calculations of CE evolution have been carried out by Taam *et al.* (*ApJ 222*,269); Delgado and Thomas (*Mass Loss and Evolution of O-type stars*, eds. Conti and De Loore, Reidel), and notably by Meyer and Meyer-Hofmeister, *AAp 78*,167, Much more work will have to be done in this field, and it is likely that CE evolution will also have important consequences for the origin of runaway radio pulsars, binary pulsars and low-mass X-ray binaries (Tutukov and van den Heuvel, *IAU Symp 93*). Also among the massive O-type binaries, even in the case of mass ratios close to unity, evolutionary losses of mass and angular momentum, in this case by strong stellar winds, are very important as was shown by Hutchings and by Conti, and their co-workers, in many investigations (see especially Massey, *ApJ*, in press). Theoretical work on the influence of wind mass loss on evolution by Chiosi and co-workers, De Loore and co-workers (notably: van Beveren and Conti, *Ap 88*,230) yields fair agreement with the observations (see the reviews by De Loore (*Space Sci Rev 26*,113) and in *IAU Symp 83*, *IAU Symp. Wolf-Rayet Stars*, De Loore and Conti, eds., Reidel 1982, and in C. de Jager: *The Brightest Stars*, Reidel 1981).

As to the evolution of very close binaries, it was found, independently, by Ritter (private communication), by Ostriker and Zytkow (private communication), by Paczynski and Sienkiewicz (*ApJ 248*,L27), and by Rappaport, Joss and Webbink (*ApJ* in press) that during evolution driven by gravitational radiation the binary period will pass through a minimum around 80 min., and subsequently increase. The existence of CV binaries with still shorter periods, as well as the high mass transfer rates observed in various types of low-mass X-ray binaries are still not understood.

The advent of Carbon-deflagration scenarios for type I supernovae, i.e. nuclear explosions of an entire C-O white dwarf as a consequence of accretion, suggests that cataclysmic variables are likely progenitors for these SNe (see the review by Sugimoto and Nomoto, *Space Sci Rev 25*,155, and by Chevalier, *IAU Symp 95*). At the same time the demonstration by Mijayi *et al.* (*PASJ 32*,303) and Nomoto (*IAU Symp 93*) that O-Ne-Mg white dwarfs may be induced by accretion to collapse into neutron stars, has provided a viable scenario for the formation of low-mass X-ray binaries.

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President of the Commission

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