42. CLOSE BINARY STARS (ETOILES BINAIRES SERREES)

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1. Introduction

By the end of the XXth General Assembly in Baltimore, the number of Commission 42 members had increased to 305. Subsequently, D. Ya. Martynov has died and 11 new members have been added.

The last Draft Report showed a healthy rate of growth in citations of Sections 117 (Close Binaries), 119 (Eclipsing Binaries), and 120 (Spectroscopic Binaries) of *Astronomy and Astrophysics Abstracts* from 1982 through 1986. The number of these citations has continued the mean trend with 976 and 1015 references for 1987 and 1988, respectively. As the Past-President remarked, these counts are considerable underestimates of the total literature concerning close binaries (hereafter, CB's). A personal appreciation of the total corpus of work is that quality remains very high and content has become much richer as more and more associations have been made with generalized stellar studies. In part, this may be traced to the ever-increasing awareness by the general community of the experiments in stellar evolution which Nature runs in CB's.

The Commission sponsored IAU Colloquium No. 107 *Algols* in August, 1988 and co-sponsored IAU Colloquium No. 103 *The Symbiotic Phenomenon* in August, 1987. It will have been lead sponsor for IAU Symposium No. 151 *Evolutionary Processes in Interacting Binary Stars* of August, 1991 and co-sponsor for at least IAU Symposium No. 148 *The Magellanic Clouds and their Dynamical Interaction with the Milky Way* and IAU Colloquium No. 129 *Structure and Emission Properties of Accretion Disks*. If attention is confined to only IAU events, the number of these of great interest to members but not sponsored by the Commission has been very large: Symposia Nos. 131, 132, 135, 143, and 147 and Colloquia Nos. 104, 106, 108, 111, 114, 115, 120, 122, and 123. The Proceedings of numerous non-IAU conferences - particularly those derived from *The International Ultraviolet Explorer* - are also replete with contributions concerning CB's. Among these are 2 of particular note: The International Workshop on Binary Stars and Stellar Atmospheres held at Osmania University, Hyderabad, India in honor of the career of K. D. Abhyankar, and the NATO Advanced Study Institute *Active Close Binaries* in Kusadasi, Turkey.

Two important volumes appeared during the past triennium. First of these is *The Eight Catalogue of the Orbital Elements of Spectroscopic Binary Systems* edited by Batten, Fletcher, and MacCarthy as *PubDAO 17*,1. Almost 1500 SB's appear in the Catalogue, a testimony to the dedicated observing and analytical efforts of numerous workers and the Editors. At the same time, there has been aired the query of whether this Catalogue and its current form will continue to serve a purpose during the foreseeable future. Secondly, Vol. III (Pavo - Vulpecula) of the 4th edition of *The General Catalogue of Variable Stars* was distributed in 1989. An effort was made to determine if a new edition of *A Finding List for Observers of Interacting Binary Stars* was desirable. The general response was a positive one but there emerged substantial difference of opinion concerning the format and vehicle useful for such a document. The matter is still being discussed. There appeared about 10 books and references volumes of likely enduring interest. Commission members may find these listed in Nos. 59 through 64 of the *IAU Information Bulletin*. Finally, there appeared the volume *Critical Observations*

D. McNally (ed.), Reports on Astronomy, Vol. XXIA, 479–504.

versus Physical Models for Close Binary Systems (Gordon and Breach Sci. Publ.) edited by K.-C. Leung from the 1985 Beijing Colloquium of the same name.

The *Bibliography and Program Notes on Close Binaries (BPN)* passed through a transition with the retirement of Tibor Herczeg after 5 years of editing the *BPN*. The general Commission membership is perhaps unaware of the sacrifices and contributions which Prof. Herczeg made to the continuation of the *BPN* while General Editor. The present Editor-in Chief is A. Yamasaki assisted by regional Editors O. Demircan, T. J. Herczeg, M. B. K. Sarma, C. D. Scarfe, and M. Vetesnik. Under their supervision Nos. 48 and 49 of the *BPN* have been distributed and No. 50 has just been distributed at the time of writing.

The interval covered by this report runs from July 1987 to June 1990. The intention to emphasize significant advances in CB studies remains as in the previous Report. Reference abbreviation conventions are also preserved from that Report but a few new ones have also been added. Some internal reorganization of contents has been undertaken. The President is most grateful to all his co-authors, whose names appear in the following Sections, and to Sybil Csigi, who prepared the final copy.

2. Broad-Base Information

A. STATISTICAL INVESTIGATIONS (Jurgen Rahe, Horst Drechsel, Atsuma Yamasaki, and R. L. Mutel)

Several extensive catalogues and statistical studies of spectroscopic binaries have been published during the period under review. Pedoussaut et al. (*AApSup 75*,441) published the 15th catalogue complementaire of Spectroscopic Binaries. It contains 436 orbits published between 1982 and 1986, increasing the contents of the complete catalogue to 1519 binary solutions. Halbwachs (*AAp 168*,161) studied statistical properties of binaries of different luminosity classes on the basis of the Yale *Catalogue of Bright Stars*(4th ed.); the fraction of single stars is evaluated to be at most 23%. It may be noted that only 7% of the stars in the Yale *Catalogue* are in Batten et al.. Batten and Fletcher (*Obs 109*,186) emphasize that our knowledge of the binaries among brighter stars is seriously incomplete and that for fainter stars knowledge must be even more limited.

Many stellar samples were studied for the incidence of binaries. Carney and Latham (*AJ 93*,116) carried out a spectroscopic survey of more than 900 FGK stars selected from the Lowell Proper Motion Survey, and found that the fraction of binaries among the high velocity stars exceeds 25%. Orbital solutions for 40 binaries of this survey are given by Latham et al. (*AJ 96*,567). From radial velocity measurements of 41 metal-deficient stars, 7 spectroscopic binaries could be identified by Jasniewicz and Mayor (*AAp 203*,329); the distribution of orbital eccentricity versus period was discussed in terms of tidal circularization. Levato et al. (*ApJSup 68*,319)investigated the frequency of spectroscopic binaries among 35 OB-Type CNO stars; practically all OBN stars are short-period spectroscopic binaries while the frequency for OBC stars is similar to that for normal supergiants. Strassmeier et al. (*AApSup 72*,291) published a catalogue of 168 chromospherically-active binaries including RS CVn- and BY Dra-class systems. A VLA survey of 103 RS CVn binaries was undertaken by Morris and Mutel (*AJ 95*,204); it yielded the radio detection of 53 systems in the 5 GHz range. For Cepheids the analysis by Kovacs et al. (*ApJ 351*,606) does not seem to support the high binary percentage claimed by Svabados (*CommKonk 34*). Among WR stars Moffat (*ApJ 347*,373) found that none of the WN8,9 stars in the LMC and MWG shows WR+O binary nature in contrast to a value of 58% for WN6,7 stars. Finally, Robinson and Shafter (*ApJ 322*,296)searched in vain for non-interacting, detached white dwarf pairs in the period interval 30s to 3hr.

The frequency of binaries in open clusters is another topic that attracts

https://doi.org/10.1017/S0251107X00010300 Published online by Cambridge University Press

continued attention. Griffin et al. (*AJ 96*,172) confirmed the membership of more than 60 spectroscopic binaries in the Hyades and give orbits for more than 20 systems. Mermilliod and Mayor (*AAp 219*,125) and Mermilliod et al. (*AApSup 79*,11) investigated the number of binaries in 5 Hyades-like open clusters and in 6 other clusters. In the former study, the authors found that 25%-33% of the red giants are binaries and that the binary incidence varied with evolutionary stage. The cutoff period for eccentric orbits apparently decreases with age. Radial velocity measurements in 20 young open clusters by Liu et al. (*AJ 98*,626) showed a large variation of binary frequency from cluster to cluster but the percentage of binaries among B- and A-type stars is greater than 33%. The authors claim that at least one-third of all cluster stars are spectroscopic binaries. Ianna et al. (*AJ 92*,347) found a relatively high binary frequency in the open cluster NGC 2287 (13 spectroscopic binaries confirmed as members). Similarly, Arnal et al. (*PASP 100*,1076) report a high percentage (44%) of main sequence spectroscopic binaries in the *open cluster NGC 6193 (6 new systems discovered). The binary frequency in IC* 2602 was investigated by Levato et al. (*RevMex 14*,414), and Levato et al. (*ApJSup 72*,323)found 31% of O9-B3 main sequence members of Coll 228 to be binaries. Duplicity among old-disk cluster subgiant stars with chromospheric emission was studied by Cameron and Reid (*MN 224*,821). These authors showed the clusters to be deficient by a factor of 3 - 5 in binaries with periods between 1 day and 50 days when compared to those in the solar neighborhood.

In contrast to open clusters, the binary frequency in the globular cluster M71 was found to be very low. Richer and Fahlman (*ApJ 325*,218) carried out a deep CCD photometric survey and conclude that only a few percent of all main sequence stars are binaries and 1% are blue stragglers. Pryor et al. (*AJ 96*,123) undertook an (unsuccessful) search for spectroscopic binaries in the globular cluster M3 with the MMT. They confirm Gunn and Griffin's (*AJ 84*,752) earlier conclusion that binaries with separations <10 AU occur less frequently among the giants of M3 than among Population I field stars.

Statistical studies of orbital properties have appeared commonly. For instance, Feker and Eitter (*AJ 97*,1139) studied binary rotation in some detail lumping the sample into 3 categories: for $P < 30$ days, only 7% - 10% of chromospherically-active binaries are asynchronously rotating; for 30 days $< P <$ 70 days, the value is 50%; while for $P > 70$ days nearly all rotate asynchronously. For metal-poor binaries, all short-period orbits are circular, but eccentric orbits appear between periods of 13 and 18 days. In order to derive the distribution of mass ratio q, Halbwachs (*AAp 183*,234) selected a set of 205 main sequence binaries from a list of 1121 catalogued pairs and found that their frequency is about twice as great near $q = 0.4$ than at unit mass ratio. This suggests a single generation process for binaries independently of the period. Trimble (*MN 242*,79), on the other hand, stresses that different investigators have obtained different forms of the q-distribution *and that the differences arise more from selection of systems* than from methods of analysis. Her analysis of a sampling of data led to a power-law distribution in q^{-1} over the range $0.1 < q < 1.0$.

Research on cataclysmic variables is a rapidly evolving field in stellar astrophysics. A very useful compilation of general properties is Ritter's catalogue. Its 4th edition (*AApSup 70*,335) contains data on 116 cataclysmic variables, 30 X-ray binaries, and 23 related objects, while the 5th edition (*AApSup* in press) will update this information to 168 cataclysmic systems, 36 low-mass X-ray binaries and 28 related objects. Another catalogue by Bruch et al. (*AApSup 70*,481)is an extensive sample of coordinates and finding charts of 90 northern dwarf novae (δ> +20) which complements the atlas of southern and equatorial dwarf novae (116 objects) by Vogt and Bateson (*AApSup 48*,383). Berriman (*AApSup 68*,41) reviewed the published distances to cataclysmic variables; he claims that values accurate to 25-50% are available only for a few systems, while secure lower limits exist for a large sample. Hameury et al. (*ApJ 327*,L77) studied the period distribution of short-period cataclysmic binaries below the period gap and noted that the only peculiarity is the period spike of AM Her systems around 114 minutes, which is in contrast to Warner and Livio's (*ApJ 322*,L95) claim of a separate clustering of SU UMa and AM Her stars in distinct period ranges.

Several surveys of radio emission from close binaries were reported. These included RS CVns and related sources (Morris and Mutel *AJ 95*,204; Drake et al. (*ApJSup 71*,905); Stewart, et al. *MN 229*,659), X-ray binaries (Nelson and Spencer *MN 234*,1105), Serpentids (Elias, *ApJ 352*,300), Algols (Stewart et al. *ApJ 342*,463);DQ Her binaries (Bookbinder and Lamb *ApJ 323*,L131); and symbiotic stars (Seaquist and Taylor *ApJ 349*,313). In addition, some readers may be interested in radio surveys of related stars: e.g., BY Dra variables (Caillault et al. *AJ 95*,887);red giants (Slee et al. *MN 239*,913); M-type dwarfs (Caillault, *AJ 97*,163; Willson et al. *AAp 199*,255); M- and C-type giants (Drake et al. *AJ 94*,1280); the failure of detections for flare stars in the Pleiades (Bastian and Dulk *AJ 95*,794); and a complete sample of all nearby stars north of declination -28D (Fomalont and Sanders, *AJ 98*,279).

Several papers have addressed the question of whether radio luminosity is correlated with other indicators of stellar activity in close binaries. Morris and Mutel (*AJ 95*,204) found no correlation between radio luminosity and rotational parameters (period, surface velocity, Rossby number) for 53 RS CVn stars. However, Slee and Stewart (*MN 236*,129) report significant correlation with surface flux for a sample of 63 active binaries, while Drake et al. (*ApJSup 71*,905) reported correlations between radio luminosity and both surface velocity and soft x-ray luminosity for a large sample of RS CVn systems.

During the past few years, there has been growing observational evidence that non-thermal radio emission (often consistent with a gyrosynchrotron or synchrotron process) is not unique to active binary systems. For example, Drake et al. (*ApJ 322*,902) and Drake (*AJ 100*,572) suspected non-thermal radio emission from several early-type single stars with VLA data while Beiging et al. (*ApJ 340*,518) reported non-thermal emission from 6 OB supergiants. Subsequent VLBI observations of several Bp stars and O supergiants observed, respectively, by Phillips and Lestrade (*Nat 334*,329) and Phillips and Titus (*ApJ 359*,L15) confirmed the non-thermal nature of the emission. In addition, Andre et al. (*ApJ 335*,940) found non-thermal emission from the magnetic B star S-1 in the Rho Oph cloud, and Skinner et al. (*ApJ 357*,L39)reported non- thermal emission from the early-type PMS star TY CrA.

B. PERIOD STUDIES (Tibor Herczeg and Alvaro Gimenez)

Work on light curves usually contains a short discussion of the orbital period if only to establish a momentary value for calculating phases. An estimated 80 to 100 systems have been observed during the triennium in order to follow minimum timings and to monitor period changes. In addition to centers mentioned in earlier reports, Ankara, Cordoba, Hyderabad, Tartu, and Uttar Pradesh - among others - have stepped up their contributions. Many studies have been published in the *IBVS* and the *JAAVSO*. As expected, the general picture remained unchanged: most studied eclipsing systems (obviously excepting the long-period ones) show period variations. About half tend to exhibit irregular variations, frequently showing discontinuous changes, while the rest can be interpreted "geometrically" or by a linear variation with time of the period. Remarks concerning apsidal rotation as a cause of period variations appear in Section 4 of this Report.

Some slow progress has been achieved in detecting third bodies around eclipsing systems by a light-time effect. A well-documented case is AR Aur (*BAC 39*, 69). IU Aur (*ChAAp 12*,298), ST Per (*ApSpSc 143*,175), and Del Cap (*ApApSc 147*,335) have also been studied. The case for V566 Oph (*ATs 1515*) was put forward as well as were those for AK Her (*ApSpSc 136*,63; *ATs 1537*) and V471 Tau (*ApSpSc 161*,221) without definite evidence. For the galactic bulge X-ray source GX1+4, a triple star orbit of 304 days is hinted at by X-ray intensity variations.

It is impossible here to cite all revelant publications but a few among more detailed period studies should be mentioned: 44 Boo (*AAp 211*,81), CQ Cep (*SovAL 13*,170), EI Cep (*ApSpSc 135*,229), V444 Cyg (*PASP 102*,749), SW Lac (*ChAAp 13*,350), Bet Lyr (*ATs 1531*), AW UMa (*ApSpSc 154*,179), and AG Vir (*IBVS3202*).

Cataclysmic variables frequently present major problems, the period often not being known well enough for a study of its variability. One such interesting case is TT Ari (*AA 37*,197; *AAp 193*,87; *AA 38*,315) with different photometric and spectroscopic periods and beats and short-term oscillations. Another highly complicated cases is that of AM CVn (*IAUColl 114*,446). Established variations of the period are usually decreasing, as in the case of EZ Hya (*AJ 97*,207). In the case of the compact object Cyg X-3, the time derivative of the X-ray period (usually assumed to be identical with the orbital period) shows behavior significantly different from that of close binaries with similar periods, as was pointed out by Molnar (*ApJ 331*,L25). It is true that some of the much-studied spin rate variations of binary X-ray sources and pulsars may be connected with orbital periods but we still lack well-founded information. In this regard, it is interesting to see attention devoted to period changes caused by assorted mechanisms, as is emphasized in the studies by Lipari and Sistero (*AJ 94*,792) and by Applegate and Patterson (*ApJ 322*,L99).

3. Observational Data

A. METHODS AND RESULTS OF LIGHT CURVE ANALYSIS (R. E. Wilson with the assistance of J. D. Mukherjee and D. Terrell)

The time window for this report is from July 1, 1987 to June 30, 1990. For a few papers it was not obvious whether they fell within that interval. Those papers have been included. A small number of references could not be checked from local holdings and were not included in the following statistics.

Table 1 lists light curve solutions for the triennium. The *BPN*, compiled by T. Herzceg and later by A. Yamasaki, was a major resource as was the *Card Catalog of Photometric Binaries*, compiled by F.B. Wood. A. Yamasaki provided the more recent *BPN* material in advance of general distribution. The entries of the table contain 236 solutions, which is larger than the number of papers, not only due to papers treating more than one binary, but also because some of the light curves were fitted by more than one procedure. There were a few instances of the same solution being published twice, in which case only one of the references is listed. Perhaps not all such duplications were detected.

Table 1. *List of Photometric Solutions*

RT And *ApJ 345*,991, *IBVS 3173*, *IBVS 3301*, *IBVS 3469*; BX And *AJ 97*,1159, *SpScRev 50*,359; DS And *AJ 95*,1466; AB And *ApJ 335*,319; ST Aqr *ApSpSc 151*,29; EE Aqr *MN 232*, 147; OO Aql *ApJ 340*,458; R Ara *SouthernStars 33*,5; SX Aur *ApJ 327*,265; TT Aur *BeijingColl*,p. 83; CI Aur *ChAAp 14*,167; HP Aur *ApSpSc 165*,1, *ApSpSc 154*,1; IU Aur *AAp 183*,61, *ChAAp 12*,298; LY Aur *AAp 221*,49; Eps Aur *SpScRev 50*,336; TY Boo *AJ 98*, 2287; AR Boo *ApSpSc 153*,273; 44i Boo *ApSpSc 151*,135, *AAp 211*,81, *IBVS 3368*; RZ Cnc *AJ 98*,1002; UU Cnc *ApSpSc 159*,67, *AA 37*,375; WY Cnc *ApJ 319*,827, *AJ 96*,1327, *IBVS 3354*, *IBVS 3384*, *IBVS 3416*; AD Cnc *AJ 98*,2287; R CMa *ApSpSc 151*,1; XZCMi *PASP 102*, 646; Del Cap *AJ 97*,499; ST Car *ApSpSc 143*,107, *ChAAp 12*,106, *SpScRev 50*,335; EM Car *AAp 213*,183; OY Car *MN 228*,729; RX Cas *AAp 185*,150, *AAp 215*,272, *SpScRev 50*,179; SX Cas *AAp 207*,37, *SpScRev 50*,179; TX Cas *BeijingColl*,p. 183; CW Cas *AAp 197*,347; DO Cas *ChAAp 12*,216; HT Cas *AJ 94*,1291, *BeijingColl*,p. 371; IT Cas *ApSpSc 155*,53; OX Cas *ApSpSc 138*,361, *AJ 98*,1418; V375 Cas *BeijingColl*,p. 131; V523 Cas *AJ 98*,2287; V541Cas *ChAAp 11*,237, *BeijingColl*,p. 131; BF Cen *SpScRev 50*,346; V701 Cen *AAp 193*, 168; U Cep *SpScRev 50*,261; VW Cep *AAp 218*,141, *IBVS 3207*; AH Cep *AAp 221*,49, *IBVS 3312*; CO Cep *ApSpSc 155*,53, *SovA 32*,530; XY Cet *ApSpSc 138*,197; Z Cha *MN 228*,797, *MN 233*, 705; RS Col *MN 227*,381; RW Com *ApJ 319*,325; CC Com *ApSpSc 141*,199, *ApJ 343*, 909; U CrB *SpScRev 50*,264; W Cru *AA 37*,41, *ApSpSc 150*,103, *AAp 185*,150; SW Cyg *AJ 96*,747; CG Cyg *IBVS 3294*, *IBVS 3305*, *IBVS 3398*; KU Cyg *AJ 96*,1439; V380 Cyg *SpScRev 50*,378; V442 Cyg *AJ 94*,712; V836 Cyg *MN 241*,559; V909 Cyg *AApSup 73*,255; V1425 Cyg *ApJ 338*,1016; RW Dor *MN 240*,931, *AA 39*,27; UZ Dra *AJ 97*,822; AG Dra *AAp 227*,121; AX Dra *ChAAp 13*,216; BVDra *AApSupp 70*,63; BW Dra *AApSup 70*,63; BY Dra *IBVS 3102*; RZ RZ Eri *SpScRev 50*,351; BL Eri *AJ 95*,894; EI Eri *ApJ 348*,682; U Gem *ApJ 321*,813; Del Gem *AAp 192*,135; TT Her *AAp 210*,181; HZ Her *SovAL 14*,427; MT Her *ApSpSc 153*,335; RH Hya *SpScRev 50*,376; RX Hya *AApSup 81*,67; TT Hya *AJ 95*,1204; AI Hya *ApSpSc 155*,53; EZ Hya *MN 227*,381, *BeijingColl*,p. 221; RS Ind *MN 232*,147; RY Ind *ChAAp 12*,106; ST Ind *ApSpSc 161*,1; AR Lac *AJ 97*,848; RR Lep *SpScRev 50*,359 & 376, *PASP 101*,180, *AApSup 81*,81; ESLib *ApSpSc 153*,273; FS Lup *AAp 183*,265; V361 Lyr *AJ 99*,1207; UX Men *AAp 211*,346; RW Mon *SpScRev 50*,373; TV Mus *MN 237*,447; V502 Oph *IBVS 3218*; V508 Oph *ApSpSc 151*,115, *AAp 231*,365; V839 Oph *ApSpSc 153*,143; BM Ori *SovAL 15*,362; ER Ori *AApSupp 74*,443; V392 Ori *BeijingColl*,p. 247; V1031 Ori *AAp 228*,365; U Peg *ChAAP 12*, 223, *ChAAp 13*,97; AG Peg *AAp 227*,121; AQ Peg *AJ 96*,747; AW Peg *AJ 96*,747; II Peg *AAp 204*,177, *IBVS 3089*, *ApSpSc 162*,205, *AAp 204*,177; RW Per *AJ 95*,1828, *AJ 97*,505; RY Per *BeijingColl*p. 215; AX Per *AAp 227*,121; Bet Per *ApJ 342*,1061, *AJ 96*,326, *ApJ 350*,372; AD Phe *MN 227*,381; AE Phe *BeijingColl*,p. 77, *IBVS 3415*; AI Phe *AAp 196*, 128; Gam Phe *ApSpSc 135*,283; X Pic *ApSpSc 140*,105; VZ Psc *AJ 97*,532, *ApSpSc 159*,67; UZ Pup *ApSpSc 153*,269; HI Pup *BeijingColl*,p. 215; RZ Pyx *MN 227*,481; U Sge *AJ 94*, 1043, *BeijingColl*,p. 215; V523 Sgr *AJ 97*,842; Ups Sgr *MN 223*,621; RY Sct *SovAL 14*, 105; RW Tau *SpScRev 50*,373; V471 Tau *AJ 97*,848; V711 Tau *AAp 204*,177; RU UMa *PASJ 40*,79; XU UMa *ApJ 319*,827; XY UMa *IBVS 3200*, *IBVS 3253*, *IBVS 3304*; IX Vel *MN 235*, 1385; BH Vir *ApJ 354*,352; CX Vir *MN 231*,397; RS Vul *SpScRev 50*,347; AY Vul *SpScRev 50*,374; DR Vul *SovA 32*,56; BD+37D2356 *AASin 29*,16, *BeijingColl*,p. 247; HD27130 *AJ 93*,1471; HD167971 *MN 235*, 797, *AAp 185*,121; HD208496 *AApSup 74*,247; HV1620 *AJ 95*, 731; HV1669 *AJ 95*,731; HV2241 *AJ 94*,1169; HV2765 *AJ 94*,1169; HV5943 *AJ 94*,1169; 3U1653+35 *ApSpSc 151*, 181; Cen X-4 *ApJ 350*,386; LMC X-3 *AAp 203*,79; LMC X-4 *AAp 223*,154; NSV12615 *MN 241*,631; M31 Anon *PASP 100*,730.

The previous triennium report contained a table of usage of the various light curve fitting and modeling procedures, along with some comments on trends and likely reasons for those trends. That table is extended below for the 1987-90 triennium in Table 2. The listing is by solutions, not by papers. Solutions of a given binary in several passbands count as one solution. Solutions with a given procedure under different constraints, or with other variations, count as one solution. Solutions with different procedures within a paper count as different solutions. The categories have been retained exactly as in the previous report and in the same order, with the only change being the addition of two categories (J. Kallrath's SIMPLEX program and A.P. Linnell's differential corrections program). If this kind of table is compiled for the next triennium, it would be appropriate at that time to revise the categories, dropping those with no usage and introducing new ones as needed. Even after the categories have been formed, there can be an occasional problem in assigning a solution to a category. This is because a "computational procedure" usually consists of a light curve computer model embedded within a parameter adjustment program, and that light curve model can be extracted and used with another parameter adjustment program. (It seems likely that this practice will continue and increase, as individuals tend to be mainly interested in one or the other of these two parts of the overall problem.) It must be decided whether the category is that of the light curve model or that of the parameter adjustment scheme. The assignments of the last column of Table 2 are based on the parameter adjustment scheme. For this triennium the only occurrences are with the WD model having been used with a fitting algorithm other than WD's differential corrections. In regard to trends of usage, the Budding procedure has taken a jump, presumably because of its usefulness for spotted stars, although many of these solutions are brief IBVS reports. The decline in use of Russell-Merrill continues, while the previous decline for the Wood model has leveled off. The increase for WD has continued.

https://doi.org/10.1017/S0251107X00010300 Published online by Cambridge University Press

Table 2. Percentages of Light curves Fitted by Various Computational Procedures

	75-78	78-81	81-84	84-87	87-90
A - Budding	2%	0%	2%	0%	12%
B - Eaton	1%	0%	1%	2%	0%
C - Hill (LIGHT)	2%	2%	1%	6%	5%
D - Kitamura	3%	4%	0%	2%	1%
E - Kopal (alpha functions)	1%	0%	0%	0%	0%
F - Kopal (frequency domain)	7%	17%	15%	12%	6%
G - Lavrov	2%	1%	0%	2%	1%
H - Miscellaneous	5%	14%	20%	19%	17%
I - Mochnacki-Binnendijk-Nagy	3%	0%	0%	3%	0%
J - Rucinski	3%	1%	3%	3%	3%
K - Russell-Merrill	23%	11%	11%	6%	1%
L - Soderhjelm	4%	0%	0%	0%	0%
M - Nelson-Davis-Etzel (NDE)	1%	2%	3%	8%	3%
N - Wilson-Devinney (WD)	13%	14%	22%	27%	44%
O - Wood (WINK)	30%	34%	21%	8%	7%
P - Yamasaki	0%	0%	1%	2%	1%
Q - Kallrath	0%	0%	0%	0%	2%
R - Linnell	0%	0%	0%	0%	1%

The interrelated areas of modeling, computation, and data treatment for brightness variations are separated below into categories. A larger number of categories and far more papers could be listed, were it not for the restrictions to new models, new supplements to models, and new ways of using models. Specifically excluded are actual parameter estimations with a pre-existing model (even where the results are remarkable or astrophysically important), modeling of explosive events and flares, computer programs based on previously published ideas, popular articles, non-quantitative ideas, and modeling outside the spectral range from the ultraviolet to the infrared. The listing of a paper in a category means only that it belongs to that category and appears to have some innovation or intention of innovation (except for reviews). A few papers are in more than one category. Category 6 covers the first few papers in which a previously published new model or procedure was used, by one or more of the original authors, so as to establish its reliability and usefulness.

Cat. 1. Models or supplements to models for normal binaries: *AAp 224*,98(gravity darkening); *ApJ 356*,613(reflection effect); *ApJ 355*,27(contact binary flow 1 effects); *SpScRev 50*,371(Householder LS algorithm); *SovA 32*,608(light curve model).

Cat. 2. Models for binaries with circumstellar features: *AAp 227*,121(reflection in symbiotics); *ApJ 335*,881(superhumps in SU UMa's); *SpScRev 50*,336(thin disk); *MN 242*,606(eclipses of white dwarfs with accretion disks).

Cat. 3. Direct spot models: *AJ 97*,848.

Cat. 4. Rectified spot models: *ApJ 319*,827; *ApJ 320*,756.

Cat. 5. Parameter adjustment and data treatment: *ApJ 313*,346(simplex); *AAp 192*,135(spots); *AAp 197*,347(search algorithm); *AA 38*,41(search algorithm and 5 error estimation); *AJ 97*,848(least squares for spots); *ApJ 349*,163(spectral decomposition for spots); *ApSpSc 134*,235(frequency domain relations); *ApJ 319*, 827(multi-step spot fitting).

Cat. 6. Follow-up on new models or procedures: *SpScRev 50*,235(rotation from light curves); *AJ 95*,1828(rotation from light curves); *AJ 96*,747(rotation from light curves); *ApJ 332*,293(spots); *ApJ 345*,991(spots); *ApJ 354*,352(spots); BeijingColl,*p*. 455 (rotation from light curves); *SpScRev 50*,269(testof computer model); *ApJ 343*, 909(use of light curve computer model); *ApJ 319*,325(spots); *ApJ 342*,449(tests of differential correction program).

Cat. 7. Spherical models, corrected spherical models, and rectification: in *Exercises in Astronomy* (ed. J. Kleczek),p. 287 (eclipse geometry); *ApSpSc 134*,235 (eclipse geometry); *Mathematical Theory of Stellar Eclipses*, (Kluwer Acad. Publ.).

https://doi.org/10.1017/S0251107X00010300 Published online by Cambridge University Press

Cat. 8. Intercomparison of models and model results: *AJ 94*,1043(WD vs. Wood); *MN 227*,481(Hill vs. Rucinski); *AAp 221*,49(WD vs. SIMPLEX).
Cat. 9. Computing innovations: *ApJ 356*,613 (efficiency).
Cat. 10. Overall strategy and logic: *BeijingColl* p. 193 (solution constraints).
Cat. 11. Reviews: None this triennium.

As the list shows, there has been considerable interest in optimizing methods of parameter estimation, especially in regard to reliable convergence and the avoidance of false solutions. A major area of increased activity is in determining the surface distributions of magnetic starspots. A few papers followed up on the recent idea of finding rotation rates from light curves. There was little light curve modeling work on the classical unique binaries, with no papers on Bet Lyr and only one brief paper on Eps Aur.

B. UV AND X-RAY "LIGHT" CURVE MODELING (Yoji Kondo and George E. McCluskey)

It takes a great deal of telescope time to obtain light curves for eclipsing binaries. As the telescope time on a satellite observatory is at a premium, not very many light curves in the ultraviolet and x-ray wavelengths have thus far been obtained. It should therefore not surprise us that systematic methods for "solving" ultraviolet or x-ray light curves are yet to be developed.

First ultraviolet light curves were obtained with the OAO-A2 Wisconsin Experiment Package. The first light curves published were those for Bet Lyr (Kondo et al. *ProcIAUColl 15*,380). They were quite unusual, with the secondary minimum deepening toward shorter wavelengths. It was clear that no conventional light curve solution method, developed for the eclipse of two bodies, could be applied to these light curves, since the light variations were affected significantly by non-eclipse phenomena such as the presence of an optically thick circumbinary plasma. On the other hand, it was possible to apply a modified Russell-Merrill method to the OAO-A2 light curves of LY Aur and derive its physical parameters, since the light variations were basically due to the eclipses of two O stars, if one allowed for the light contributed by a third star located at 0.5 arcsec from the binary (McCluskey & Kondo *ApJ 187*,93).

In the absence of any systematic methods for solving the "light" curves, investigators have resorted in most cases to the use of various astrophysical considerations and assumptions in deriving the physical parameters from the UV and x-ray "light" curves. For instance, in obtaining physical parameters for x-ray binaries, they often assume that the "normal" companion to the collapsed object fills its critical Roche equipotential surface.

We will cite below several examples of papers on this subject. Since this is the first review of this subject in the triennial report of Commission 42, we will not limit these citations to articles published in the 1987-90 period. The paper by Eaton et al. (*ApJ 296*,222) deals with ultraviolet observations, while those by Ghosh et al. (*ApJ 251*,230) and Hellier and Mason (*MN 239*,715) concern x-ray results.

C. SPOT-CURVE MODELLING FOR ECLIPSING AND NON-ECLIPSING SYSTEMS (M. Rodono)

The interpretation of low-amplitude, quasi-periodic photometric variations in terms of cool-spot visibility modulated by stellar rotation has been addressed only recently in a systematic way. The first IAU-sponsored meeting that explicitly considered starspots as an important aspect of solar- like activity was *IAU* Colloquium No. 71 *Activity in Red Dwarf Stars*. Since then several meetings with major parts dedicated to starspots have been held, e.g., the series of Cambridge Workshops (hereafter, *CambrWork*)on *Cool Stars, Stellar Systems, and the Sun* a JD at the IAU GA in New Delhi, a JCM at the IAU GA in Baltimore, and more recently an entire colloquium *Surface Inhomogeneities in Late-type Stars* (Byrne and Mullan, *LectNotPhys*, in press) to celebrate the Armagh Observatory Bicentenary. Comprehensive lists of references can be found in the *Proceedings* of all these conferences.

Both eclipsing and non-eclipsing systems include spotted cool stars. Therefore, eclipsing system light curves need first to be cleaned of proximity and eclipse effects. The residual light variation or the *distortion wave*, so-called to emphasize its distorting effects on the observed light curve, is then modelled in terms of cool spots, as is directly done for non-eclipsing systems.

The basic spot modelling method, first outlined by Torres and Ferraz-Mello (*AAp 27*,231) and Friedman and Gurtler (*AN 296*,125),has been improved in the recent years (e.g., Rodono et al. *AAp 165*,135; Zeilik and Budding in *Fifth CambrWork*,p. 500)by allowing in the model any number of spots of any size and location on the stellar surface in order to reproduce the observed wave-like light curve. The large number of free parameters (inclination of the rotation axis, spot size and temperature, spot number and positions, limb darkening coefficients, for each of the spotted stars in the system) very seldom leads to unambiguous solutions. Generally, unique solutions are not possible because substantially identical solutions can be found with different parameter combinations, e.g., by trading off spot dimension and temperature, and spot latitude and inclination of the rotation axis. The latter ambiguity is avoided for eclipsing systems with accurately known orbital inclinations. The times of eclipses offer precise time reference marks to monitor the migration of the distortion wave on the light curve. The migration rate and its variation can be used to estimate stellar differential rotation, which, quite surprisingly for such active stars, appears to be 1 - 2 orders of magnitude smaller than solar (Busso and Scaltriti in *Fourth Cambr Work*,p. 81;Rodono in *HighAstr* 7,429,and references therein). Smaller differential rotations are generally derived for shorter period systems, possibly because of stronger tidal coupling.

Remarkably, photometric investigations on starspots and their spatial correlation with chromospheric plages (cf., Rodono *HighAstr* 7,429; *Fourth CambrWork*,p. 475) indicate huge spots or spotted areas covering up to 30% - 40% of the projected stellar disk and spot temperatures cooler than the surrounding photosphere by 400K - 1500K. Both equatorward and poleward migrations have been inferred from modelling a series of closely spaced light curves. Starspot temperatures and dimensions, however, are affected by severe observational selection: smaller solar-like and/or hotter spots would give rise to undetectable light variations. The question of spatial correlation between photospheric spots and overlying chromospheric plages is still open: both positive and negative results are equally well documented (Gondoin *AAp 160*,73; Rodono et al. *AAp176*, 267; Butler et al. *AAp174*,139; Andrews et al. *AAp 204*,177; Doyle et al. *AAp 223*,219).

In order to achieve reasonably unique solutions, photometry should be assisted by high-resolution spectra of rotationally-broadened line profiles that can be used to obtain spot parameters and positions on the stellar surface by means of the so-called *Doppler imaging* (Vogt and Penrod *PASP 95*,565) or *maximum entropy* (Collier-Cameron and Horne *FourthCambrWork*,p.205; Vogt et al. *ApJ 321*,496) method. These methods, on the other hand, need concurrent and accurate *VRI* photometry to resolve the ambiguity between spot temperature and dimension.

Both observational and theoretical studies of starspots have clearly demonstrated that long-term systematic monitoring of selected eclipsing and non-eclipsing systems is essential in order to derive valuable information on the evolution of spot activity by modelling their light curves at the times of gradual and abrupt changes. Moreover, these observations can address the important question of cyclic stellar activity.

D. RADIAL VELOCITY CURVE ANALYSES (R. W. Hilditch)

The *Eighth Catalogue of the Orbital Elements of Spectroscopic Binary Systems* (*PubDAO 17*) was published in the middle of the past triennium, and, with 1469 entries (50% greater than the *Seventh Catalogue*), reflects the substantial increase over the last few years in the rate of acquisition of radial velocity data and the determination of orbital elements. Two short papers by Fletcher and Batten (*JRASC 84*,44) and Batten and Fletcher (*JRASC 83*,289) result directly from the *Eighth Catalogue* in discussing some of the general properties of known spectroscopic binaries, and the frequency of multiple systems.

The Table of references in this section includes all papers in which spectroscopic observations are reported, with at least some attempt to determine radial velocities from spectral features. Hence most papers provide the determination of radial velocities of one or both stellar components together with orbital solutions. A significant number of contributions concentrate on spectrophotometric studies of phase-dependent line-profile variations with only limited radial velocity studies *per se*; nevertheless, it seems appropriate to include such work in this section. In this latter context, reference should be made to the spectrophotometric surveys of cataclysmic variables by Friend et al. (*MN 233*,451), Verbunt (*AApSup 71*,339), and La Dous (*SpScRev 52*,203), as well as to many such observations of symbiotic stars reported in *IAUColl No.103*. Surveys of particular types of stars to establish radial velocity variations due to orbital motion have also been undertaken by Manteiga et al. (*AAp 210*,66), Moffat (*ApJ 330*,766), and Cowley et al. (*ApJ 333*,906).

The literature survey is as complete as possible up to June 1990. Abstracts of papers presented at meetings (e.g., *BAAS*) have not been included since, invariably, they are superseded by full papers with complete accounts of all observations and analyses. A few publications report radial velocities and orbital solutions for large numbers of binaries (e.g., Balona (*SAAOC 11*,1) with 35 systems); the stars appear individually in the following listing.

Table 3. List of Radial Velocity Analyses

Z And *IAUColl 103*,27, *ApJ 324*,1016; RX And *ApJ 330*,305; TW And *ApJSup 71*,595; AB And *ApJ 335*,319; BX And *MN 244*,328; DS And *AJ 95*,1466; DX And *AApSup 78*,145; EG And *AAp 198*,173, *IAUColl 103*,27; KX And *BAC 41*,29; Omi And *PASP 100*,243, *AN 310*,145; RY Agr ApJSup 71,*595; EE Aqr* MN 232,*147; FO Aqr* ApJ 342,*493,* MN 242,*250; FF Aql* AJ 99, 1598; KP Aql *AJ 94*,1673; OO Aql *ApJ 340*,458; V923 Aql *BAC 40*,31; V1315 Aql *AJ 94*, 1055; UX Ari *AJ 98*,1398; Bet Ari *AJ 94*,1664, *Obs 108*,228; Del Aql *AJ 98*,686; UV Aur *IAUColl 103*,27; 44i Boo AAp *208*,201, AAp*211*,81; AY Cam *AJ 94*,1670; 53 Cam *AN 309*, *33,* AN 310, *213; YZ Cnc* AJ 95,*178; R CMa* MN 241,*777; UW CMa* Obs 109,*74; RS CVn* AJ *95*,1242, *AAp 231*,375; TX CVn *IAUColl 103*,27, *AJ 97*,194; VZ CVn *AJ 95*,190; AI CVn *PASP 102*,328; EM Car *AAp 213*,183; OY Car *AAp 213*,167; RX Cas *AZh 64*,591, *AAp 215*, 272; SX Cas *AAp 207*,37; AO Cas *Obs 108*,174; IX Cas *AJ 98*,981; V641 Cas *AJ 97*,836; XX Cen *MN 242*,285; V701 Cen *AAp 193*,168; V803 Cen *MN 236*,319; V834 Cen *MN 244*,20P; Cen X-4 *AJ 95*,1231; U Cep *ApJ 339*,420, *ApJ 332*,1019; VV Cep *AAp 225*,143; VW Cep *AAp 218*,141, *AJ 94*,1051; CQ Cep *TartuObs 89*,126, *ApJ 351*,651; GP Cep *ApJ 344*,870; NY Cep *AAp 231*,89; 5 Cet *AA 38*,353; Z Cha *MN 231*,1, *ApJ 324*,411; 35 Com *PASP 100*,358; SS Cyg *MN 240*,975; CH Cyg *TartuObs 86*,3, *IAUColl 103*,27; CI Cyg *IAUColl 103*,27; V367 Cyg *PisAZh 15*,247; V389 Cyg *Obs 109*,225; V442 Cyg *AJ 94*,712; V444 Cyg *PASP 100*,741 & 1256, *AAp 226*,137, *PisAZh 14*,248; V1016 Cyg *AAp 197*,161; V1329 Cyg *PisAZh 15*,140, *PASP 101*,189; V1500 Cyg *ApJ 343*,888; V1727 Cyg *ApJ 341*,L75, *AJ 99*,678; Xi Cyg *PubAICzAcadSc 70*,331, *AAp 214*,261; 59 Cyg *PubAICzAcadSc 70*,127; TX Del *AJ 98*, 981; TW Dra *ApJSup 71*,595; WW Dra *AJ 96*,1040; AG Dra *IAUColl 103*,27; The Dra *AApSin 8*,99; 4 Dra *AAp 193*,180, *AAp 214*,261; 6 Dra *JApA 11*,255; RZ Eri *AJ 96*,1040; BL Eri *AJ 95*,894; EF Eri *AAp 190*,L29; RX Gem *ApJSup 71*,595; RY Gem *PASP 100*,594; IR Gem *AJ 96*,1702; Gam Gem *AJ 94*,1302; Eta Gem *AAp 214*,261; Sig Gem *PASP 101*,516; Z Her *AJ*

https://doi.org/10.1017/S0251107X00010300 Published online by Cambridge University Press

95,1242; AD Her *ApJSup 71*,595; MM Her *AJ 96*,1040; RW Hya *ApJ 316*,427, *IAUColl 103*, 27; TT Hya *ApJSup 71*,595, *AJ 95*,1204; AI Hya *AJ 95*,190; EX Hya *MN 228*,463, *MN 238*, 1107, *ApSpSc 163*,59; KW Hya *AAp 175*,355; Eps Hya *CAOSkalPleso 16*,17; RS Ind *MN 232*, 147; SW Lac *AApSin 9*,217; AR Lac *AAp 215*,79, *ApSpSc 166*,177; XY LeoB *ApJ 317*,333; UZ Lib *AAp 223*,172; Del Lup *AApSup 76*,121; Bet Lyr *AAp 193*,202; MV Lyr *AAp 192*,128; UX Men *AAp 211*,346; T Mon *AAp 216*,135; VV Mon *AJ 96*,1040; AU Mon *ApJSup 71*,595; AX Mon *BAC 40*,118; DD Mon *AJ 99*,1219; S Mus *PASP 102*,551; TV Mus *MN 237*,447; V426 Oph *AApSup 72*,515, *MN 242*,32P; V502 Oph *AAp 231*,365; V566 Oph *AAp 218*,152; V1010 Oph *PASP 100*,371; 70 Oph *JRASC 82*,140; Alp Oph *AJ 98*,686; V643 Ori *AApSup 71*,69; V1031 Ori *AAp 228*, 365; Del Ori *Obs 107*,205; Thel OriA *AAp 222*,117; U Peg *ApSpSc 146*,1, *AASin 29*,9; AG Peg *IAUColl 103*,27; II Peg *AAp 214*,227, *AAp 223*,219, *AAp 224*,153; IP Peg *MN 231*,1117, *MN 240*,519, *AJ 94*,1051; RW Per *ApJSup 71*,595; RY Per *ApJSup 71*, 595; AX Per *ApSpSc 150*,235; KS Per *AApSup 75*,157, *ApSpSc 158*,223; LX Per *AJ 96*, 1040; NS Per *AApSup 78*, 145; Bet Per *AAp 219*,219; Gam Per *AJ 94*,700; AI Phe *AAp 196*,128; SZ Psc *AJ 96*, 1040; VX Psc *AJ 97*,532; TY PsA *MN 238*,73; XY Pup *ApJSup 71*, 595; CP Pup *MN 240*,41; RZ Pyx *MN 227*,481; Del Sge *AAp 214*,261; X Sgr *MN 242*, 285; V350 Sgr *MN 242*,285; AK Sco *AAp 219*,142; MR Ser *PASP 100*,791; V471 Tau *AJ 96*,157 & 976, *ApJ 341*,L17; V711 Tau *AAp 211*,173, *ApSpSc 152*,85; V725 Tau *AAp 195*,148; Zet Tau *ApSpSc 139*,83; 88 TauA *AAp 200*,175; TX UMa *AZh 64*,1256; AA UMa *AApSin 8*,26; DW UMa *ApJ 327*,248; Mu UMa *AAp 214*,261; Omg UMa *PubAICzAcadSc 70*,321; RR UMi *AAp 214*, 261; RU UMi *PASJ 40*,79; IX Vel *MittAG 70*,369; Gam2 Vel *Obs 110*,1; CX Vir *MN 231*, 397; RS Vul *ApJSup 71*,595; PU Vul *AAp 223*,119; Lam Vir *Obs 110*,43; HR616 *Obs 109*, 142; HR965 *Obs 109*,180; HR2577 *PASP 100*,481; HR5110 *MN 228*,869; HR6005 *Obs 108*,155; HR7275 *MN 238*,675; HR8581 *AApSup 75*,167; HD245 *AJ 96*,567; HD1833 *SAAOC 11*,1; HD3196A *AAp 171*,157; HD3266 *AJ 96*,567; HD5303 *SAAOC 11*,1; HD5373 *Obs 109*,79; HD6755 *AAp 203*,329; HD7426 *Obs 108*,90; HD7640 *AJ 96*,567; HD8435 *SAAOC 11*,1; HD8634 *AAp 171*,157; HD8997 Obs *107*,194; HD9939 *AJ 96*,567; HD10308 AAp *171*,157; HD10909 *SAAOC 11*,1; HD13974 *AAp 195*,129; HD14643 *SAAOC 11*,1; HD16448 *Obs 109*,12; HD16620 *AAp 195*, 129; HD17084 *SAAOC 11*,1; HD17433 AAp *195*,129; HD19754 *SAAOC 11*,1; HD20214 *Obs 108*, 49; HD20507 *AJ 96*,567; HD22468 *SAAOC 11*,1; HD23439B *AJ 96*,567; HD26327 *ApJ 348*,682; HD26337 *SAAOC 11*,1; HD26354 *SAAOC 11*,1; HD27130 AAp *171*,157; HD27483 AAp *171*,157; HD34802 *SAAOC 11*,1; HD36486 *ApJSup 68*,319; HD37824 *SAAOC 11*,1; HD37847 *SAAOC 11*,1; HD41724/5 *AApSup 75*,305; HD42504 *SAAOC 11*,1; HD43246 *PASP 102*, 312; HD43905 *AAp 171*,157; HD46697 *SAAOC 11*,1; HD47129 *RevMex 19*,15; HD53299A *JRASC 82*,128; HD61245 *SAAOC 11*,1; HD61994 *AAp 195*,129; HD64096 *AAp 195*,129; HD64606 *AJ 96*,567, *AAp 203*, 329; HD66751 *AAp195*,129; HD71071 *SAAOC 11*,1; HD72688 *SAAOC 11*,1; HD72754 *ApJSup 68*, 319; HD81357 *BeijingColl*,p. 8 & p. 233; HD81410 *SAAOC 11*,1; HD81564 *Obs 110*,40; HD81809 *AAp195*,129; HD83442 *SAAOC 11*,1; HD85091 *AJ 96*,567; HD85217 *AAp 171*,157; HD90442 *Obs 107*,248; HD93028 *ApJSup 72*,323; HD93075 *JRASC 83*,26; HD93130 *ApJSup 72*, 323; HD93191 *ApJSup 72*,323; HD93576 *ApJSup 72*,323; HD95638 *AAp 171*,157; HD100018A *AAp 171*,157; HD101309 *SAAOC 11*,1; HD101379 *SAAOC 11*,1; HD105056 *AAp 213*,161; HD105287A *AApSup 76*,459; HD106947 *JApA 9*,127; HD107760 *AAp 171*,157; HD108754 *AJ 96*, 567, *AAp 203*,329; HD109510 *AAp 171*,157; HD110533 *AAp 171*,157; HD111425 *JApA 10*, 439; HD115968 *AJ 96*,567; HD116093 *JApA 9*,205; HD117126 *AJ 96*,567; HD118216 *AAp 171*, 157; HD118234 *JApA 9*,75; HD118238 *SAAOC 11*,1; HD118981 *AJ 96*,567; HD119285 *SAAOC 11*,1; HD122767 *Obs 108*,220; HD124425 AAp *171*,157; HD127208 *PASP 102*,312; HD131861 *AAp 171*,157; HD134646 AAp *171*,157; HD136905 *SAAOC 11*,1; HD137164 *SAAOC 11*,1; HD144284 AAp *171*,157; HD144515A/B *AAp 171*,157; HD145206 *AAp 224*,L31; HD149414 *AAp 203*,329; HD150682 *AAp 171*,157; HD152667 *ApJSup 68*,319; HD153631 *AAp 195*,129; HD153487 AAp *203*,329; HD153919 *ApJ 352*,698; HD158393 *SAAOC 11*,1; HD160922 *AAp 171*, 157; HD163181 *ApJSup 68*,319; HD165921 *PASP 100*,1436; HD167971 *AAp 185*,121; HD169385 Obs *108*,16; HD170153 AAp *203*,329; HD174853 *AJ 95*,199; HD177390/1 AApSup *75*,305, Obs *108*,114; HD178619 *AAp 171*,157; HD179143/4 *Obs 109*,55; HD181144 *AAp 171*,157; HD181809 *SAAOC 11*,1; HD182776 *SAAOC 11*,1; HD185510 *SAAOC 11*,1; HD189578 AApSup *78*, 441; HD190061 *AJ 96*,567; HD190540 *SAAOC 11*,1; HD191262 *JApA 11*,43; HD192163 *AAp 226*,249; HD192867 *Obs 110*,85; HD195987 *AJ 96*,567; HD196960 *Obs 109*,222; HD196972 *Obs 110*,7; HD200077 *AJ 96*,567; HD202134 *SAAOC 11*,1; HD202275 *AAp 195*,129; HD203454 *AAp 171*,157; HD204128 *SAAOC 11*,1; HD205249 *SAAOC 11*,1; HD206901B *AAp 171*, 157; HD207739 *PASP 102*,535; HD207826 *AAp 171*,157; HD211853 *AAp 227*,117; HD217344 *SAAOC*

11,1; HD221264 *AJ 99*,373; HD224930 *AAp 203*,329; HDE226868 *ApJ 321*,425, *ApJ 321*,438; HDE305516 *ApJSup 72*,323; HDE305536 *ApJSup 72*,323; BD+5D3080 *AJ 96*,567; BD+10D3711 *AJ 96*,567; BD+13D13 *AJ 96*,567; BD+13D3683 *AAp 203*,32, *AJ 96*,567; BD+17D4708 *AJ 96*, 567; BD+21D2321 *AJ 96*,567; BD+28D413 *Obs 107*,154; BD+30D2130 *AJ 96*,567; BD+36D2193 *AJ 96*,567; BD+37D2356 *AApSin 8*,259; BD-3D2535 *AJ 96*,567; COD-48D1741 *AAp 188*,39; A0535+26 *PbAICzAcadSc 70*,121; A0538-66 *MN 238*,595; A0620-00 *ApJ 345*,492; CW1103+254 *MN 226*,209, *PisAZh 13*,495; E1405-451 *ApJ 327*,328; E2003+225 *MN 226*,209; EXO032957 -2606.9 *AAp 219*,L7; EXO033319-2554.2 *ApJ 337*,832; G65-22 *AJ 96*,567; G87-45 *AJ 96*, 567; G87-47 *AJ 96*,567; G88-10 *AJ 96*,567; G89-14 *AJ 96*,567; G103-50 *AJ 96*,567; G171-23 *AJ 96*,567; G176-27 *AJ 96*,567; G175-56 *AJ 96*,567; G190-10 *AJ 96*,567; G206-34 *AJ 96*,567; G208-44AB/45 *ApJ 333*,943; G215-47 *AJ 96*,567; G217-2 *AJ 96*,567; G230-45 *AJ 96*,567; G236-38 *AJ 96*,567; G262-14 *AJ 96*,567; GD552 *AAp 228*,387; Gl 319 *AAp 200*, Gl 135; Gl 570B *AAp 200*,135, *AAp 230*,77; Gl 623 *ApJ 341*,961; Gl 623B *ApJ 319*,L93; Gl 735 *AAp 200*,135; Gl 815 *AAp 200*,135; HBV475 *PASP 101*,250; H0538+608 *ApJ 346*,941; LMC-Br22 *ApJ 348*,232; LMC-Br26 *ApJ 347*,373; LMC-Br31 *ApJ 348*,232; LMC-Br32 *ApJ 348*, 232; LMC-Br65 *ApJ 347*,373; LMC-Br90 *ApJ 347*,373; LMC X-1 *AJ 94*,340; LT-5 *AAp 180*, 145; MR 111 *ApJ 344*,870; MWC 623 *AAp 223*,165; M5-V101 *MN 241*,25P; M15-AC211 *IAUColl 95*,697, *MN 233*,285, *MN 236*,1P; NGC752-H300 *PASP 98*,1321; NSV12615 *MN 234*,291; PG1550+191 *MN 226*,209; SMC-AB8 *ApJ 348*,232; XB1636-536 *MN 231*,663; 1H0542-407 *ProcASAus 7*,151, *ApJ 344*,786; 4U1907+09 *AAp 209*,173; 4U2127+12 *ApJ 344*,786; 4U2129 +47 *AAp 217*,108; 045251+3016 *AJ 98*,987; 155913-2233 *AJ 98*,987; 160814-1857 *AJ 98*, 987; 160905-1859 *AJ 98*,987; 162814-2427 *AJ 98*,987; 162819-24235 *AJ 98*,987.

E. POLARIZATION CURVE ANALYSES (A. M. Cherepashchuk and R. H. Koch)

Predictive papers over the last triennium appear to have been rather few but they show considerable breadth. For instance, Kii (*PASJ 39*,781) points out that X-ray polarization from binary X-ray pulsars is possibly detectable with present technology. Cheng et al. (*ApJ 328*,223) have studied the optical and UV polarization from e-scattering accretion disks associated with nova-like variables and dwarf novae. Robert et al. (*ApJ 347*,1034) emphasize the power of polarimetry in understanding and modelling the wind flow and sporadic activity in their study of WR objects. Brown and Fox (*ApJ 347*,468) show that azimuthal and radial density distributions in disks are recoverable from polarimetry if the disks are very flat ones viewed edge-on. Lastly, stellar limb polarization has been treated by Landi Degl'Innocenti et al. (*AAp 204*,133).

Reviews based on observational surveys include Koch's (*BeijingColl*,p. 151) historical critique; the more specialized concentration by Koch et al. (*SpSciRev 50*,63) on Algols and related objects; the treatment by Kucinskas (*AN 311*,69) of novae data showing the development of graphite grains during the evolution of nova shells; and the evaluation by Magalhaes (*IAUColl 103*,p. 89) of polarization states and variability for symbiotic variables.

Observational programs have been reasonably productive. Mention should particularly be made of the survey by Liu and Tan (*AASin 28*,139) of 31 spotted star binaries (not listed individually below). Symbiotic objects (also not listed individually below) have received much attention from Bochkarev and Karitskaya (*TartuObs 89*,234), Khudyakova (*IAUColl 103*,p. 101), and Schwarz et al. (*IAUColl 103*,p. 103). For other types of binaries the concentration on circular and elliptical polarimetry of polars and linear polarimetry of WR binaries is very noticeable in the citation list which follows. With respect to WR pairs, mention should be made of the summaries in *ESA SP-281*,p. 129 and *ApSpScLib 136*,237. Of the order of 25 (WR + O) binaries have now been studied for orbital inclinations, mass loss rates, and wind instabilites. The increase of mass loss rate with mass of the WR component has been confirmed.

There follows a list of individual binaries observed polarimetrically.

Table 4. List of Polarimetric Analyses

N And86 *PASJ 40*,491; EZ CMa *ApJ 343*,426; BG CMi *ApJ 322*,L35; V834 Cen *ApJ 318*,326, *MN 236*,935; VV Cep *AJ 94*,484; CX Cep *ApJ 337*,872; Y Cyg *PASP 101*,279; V1357 Cyg *ApJ 344*,830; V1500 Cyg *IAUC 4415*, *IAUC 4458*, *ApJ 332*,282; V1819 Cyg *AJ 98*,297; EF Eri *AAp 183*,L1, *AAp 186*,120, *AGAbstr 2*,43; AM Her *AG Abstr 4*,45 & *MN233*,395; BL Hyi *AAp 185*,189, *AAp 222*,132; N Mon75 *PASP 101*,1135; VV Pup *ApJ 342*,L35; V3885 Sgr *IBVS 3385*; MR Ser *RevMex 16*,87; GP Vel *AAp 202*,124; PU Vul *AAp 223*,119; HD9974 *ApJ 337* 872; HD68273 *ApJ 322*,870; HD76536 *ApJ 343*,902; HD86161 *ApJ 322*,888; HD90657 *ESOMess 49*,26; HD92740 *ApJ 322*,888; HD93131 *ApJ 322*,888; HD93162 *ApJ 322*,888; HD93205 *ESOMess 49*,26; HD96548 *ApJ 322*,888 & *ApJ 343*,902; HD97152 *ApJ 322*,870 & *ApJ 343*, 902; HD113904 *ApJ 322*,870; HD149404 *AApSup 74*,427; HD152248 *AApSup 74*,427; HD152270 *ApJ 322*,870; HD152667 *AAp 202*,124 & *AApSup 74*,427; HD153919 *AAp 202*,124; HD164270 *ApJ 322*,870 & *ApJ 337*,872; HD190918 *ApJ 347*,1034; HD191765 *ApJ 347*,1034; HD192163 *ApJ 347*,1034; HD192641 *ApJ 347*,1034; HD193077 *ApJ 347*,1034;HD193576 *ApJ 347*,1034; HD193793 *ApJ 347*,1034; HDE311884 *ApJ 350*,767 & *ESOMess 49*,26; A0538-66 *MN 236*,901; IC 14-52 *ApJ 337*,872; EXO023432-52 *IAUC 4491* & *MN 234*,19P; EXO032957-2606 *IAUC 4866* EXO033319-2554.2 *IAUC 4517* & *ApJ 329*,L97 & *ApJ 337*,832; 4U0541+60 *IBVS3104*; Hawkins V1 *IAUC 4904*.

F. RADIO FLUX MODELLING (R. L. Mutel)

The envelope of a binary component or of the binary itself may emit significant amounts of radio flux. The information retrieved from these data can be just as important for understanding the system as its photospheric radiation.

Wideband (MkIII) VLBI techniques to probe the structure of radio emission regions developed rapidly over the past three years. Perhaps the most important advance was the use of phase-referenced VLBI to extend the coherent integration time to several hours, allowing maps of much weaker sources, as well as absolute position measurements to milliarcsecond (mas) accuracy. White et al. (*AJ 99*,405) and Lestrade et al. (*AJ 96*,1746) measured the absolute positions of several RS CVn stars to 10mas accuracy, while Lestrade et al. (*AJ 99*,1663) mapped the emission of of Algol during a very low state (3mJy) with position uncertainty of 0.5 mas.

Other VLBI observations of stellar binaries included multi-frequency, multi-epoch observations of Algol by Lestrade et al. (*ApJ 328*,232); detection of a non-spherical source during a flare of the recurrent nova RS Oph by Taylor et al. (*MN 237*,81); brightness temperature measurements of UX Ari and several Algol binaries by Massi et al. (*AAp 197*,200); and detection of a radio jet in Cyg X-3 by Molnar et al. (*ApJ 331*, 494).

The use of dynamic spectra to study stellar radio flares was pioneered by Bastian and Bookbinder (*Nat 326*,679), Bastian et al. (*ApJ 353*,265), and Gudel et al. (*AAp 220*,L5) who detected highly polarized, narrow-band bursts from several flare stars. They interpret the bursts in terms of an electron- cyclotron maser.

Penninx et al. (*Nat 336*,146) reported an interesting correlation between radio luminosity and spectral state on an x-ray color-color diagram for LMXRB GX17+2. They speculate that this connection is common to all LMXRBs. Rucinski and Seaquist (*AJ 95*,1837) studied weak radio emission from the contact binary VW Cep, which emission they attribute to non-thermal coronal emission of dimension 1-3 solar radii. Wright et al. (*MN 231*,319) detected V834 Cen, the second radio detection of an AM Her-type system. Bastian et al. (*ApJ 324*,431) reported radio flares from the DQ Her-type systm AE Aqr which they model as a superposition of expanding synchrotron sources.

Several papers reported simultaneous observations of binary systems at radio and x-ray, UV and other wavelengths. Van den Oord et al. (*AAp 205*, 181; *AAp 209*,296) reported on combined radio and X-ray observations of Sig Crb and Algol during X-ray flares. They conclude that for Algol the radio and X-ray sources are probably cospatial. Linsky et al. (*AAp 211*,173) reported simultaneous radio and UV observations of a bright flare of V711 Tau. They modelled the flare with a large starspot; the radio emission was attributed to gyrosynchrotron emission from magnetic flux tubes above the spot. Lang and Wilson (*ApJ 328*,610) found no correlation between UV and radio flare activity in UX Ari and HR 1099. Garcia et al. (*ApJ 328*,552) also find no correlation between X-ray and radio flux variations for LMXRB GX13+1. Kundu et al. (*AAp 195*,159) also report no correlation between radio and x-ray flares for several red dwarf flare stars.

4. Stellar Physical Data (A. Gimenez)

Absolute Dimensions

For brevity in the following, authors' names are cited for conceptual studies but not for analyses of individual binaries.

Compilations of absolute dimensions derived from close binaries have been published by Svechnikov (*ATs 1525*; *ATs 1527*) and Harmanec (*BAC 39*,329). Fundamental stellar properties have been collected from the literature in order to provide average relations in terms of spectral types or effective temperatures. The Copenhagen Eclipsing Binary Program continued to provide high-quality data on the basis of coordinated photometric and spectroscopic observations of selected double-lined eclipsing binaries. Analyses of these data show that one-dimensional calibrations are inadequate to fit the most accurate absolute dimensions, even for the main sequence pairs as has been emphasized by Andersen (*BullCDS 33*,59). In particular, Nordstrom (*ApJ 341*,934) cautioned against the use of a "unique" spectral type-mass relation. The use of binary systems as a tool for testing models for single-star "undisturbed" evolution was reviewed by Andersen (*HighAstr 8*,145).

Computations by Pedersen et al. (*ApJ 352*,279) and Beech and Mitalas (*ApJ 352*,291) of evolutionary models for core-hydrogen-burning phases, with special attention to the effects of different convection theories, have been revitalized by the good determinations now available. A new grid of models has been given by Claret and Gimenez (*AApSup 81*,1) for the analysis of double-lined eclipsing binaries as an updating of Hejlesen's work. Models with mass loss and overshooting, and with a more general astrophysical scope, have been published by Maeder (*AAp 210*,155; *AApSup 84*,139). Precise location of the ZAMS has been studied by VandenBerg and Poll (*AJ 98*,1451) from the point of view of pre-main-sequence depletion of Li and by Stothers and Chin (*ApJ 348*,L21) for limiting convective core overshooting. Binaries located around the TAMS seem nevertheless to be more suitable to show the effects of overshooting. This is the case for V1031 Ori (*AAp 228*,365) with accurate dimensions derived from high-dispersion spectrograms and uvby photometry. The component stars are found in a very short-lived evolutionary phase unless convective overshooting is taken into account. On the other hand, EM Car (*AAp 213*,183) provides accurate parameters at the upper end of the main sequence for an O8 V system. Available models with and without overshooting reproduce the observed dimensions equally well but the fast apsidal motion shows a significant discrepancy with theoretical expectations. Hilditch and Bell (*MN 229*,529) compiled absolute parameters for 31 O-B5 systems and detached components were compared with main-sequence models showing, once more, the importance of convective overshooting and mass loss. Other early-type binaries studied are: OX Cas (*AJ 98*,1418), XY Cet (*ApSpSc 138*,197) and NY Cep, for which absolute dimensions could only be estimated (*AAp 231*,89). Re-analyses of LY Aur and AH Cep showed the need for careful consideration of third light (*AAp 221*,41). Additional comparisons with models include YZ Cas (*ApSpSc 153*,213) for stellar rotation, V380 Cyg (*Ap 29*,591) for internal structure, and QX Car and V539 Ara (*AAp 213*,195) considering future evolution with mass transfer.

A first attempt to show the viability of getting high-accuracy light curves of eclipsing binaries in the LMC and SMC has been made by Jensen et al. (*AApSup 74*, 331). Davidge (*AJ 94*,1169; *AJ 95*,731) estimated absolute dimensions using photometric data only but some spectroscopic measurements have also been obtained by Niemela (*RevMex 14*,390). CCD photometry and modern detectors to obtain radial velocities now permit exploring chemical and evolutionary environments different from those in our galaxy.

Late-type binaries deserve continuing attention for the determination of fundamental properties in order to provide a broad data base to understand the behaviour of stars below the Sun on the main sequence where reliable information is scarce. Visual and spectroscopic binaries have been used by Bohm (*ApSpSc 155*, 241) to derive an empirical MLR, and Popper et al. (*BeijingColl*,p. 49) reported the first reliable masses and radii of main sequence G-type stars. Individual cases studied in the reviewed triennium include the main sequence systems UZ Dra (*AJ 97*,822), V442 Cyg (*AJ 94*,712) and KP Aql (*AJ 94*,1673) and the evolved systems AY Cam (*AJ 94*,1670), V643 Ori (*AApSup 71*,69) and W Gru (*AA 37*,41). A possible surface- brightness anomaly for late-type main-sequence binaries, pointed out by Lacy et al. (*AJ 94*,1035), requires further study. An important analysis of the study case AI Phe, an evolved F+K-type binary with accurate absolute dimensions has been done by Andersen et al. (*AAp 196*,128) using metal abundances independently obtained through high-resolution CCD spectra. Models computed by VandenBerg (*ApJSup 51*,29) show a remarkably good agreement with observed parameters. The similar, less evolved, system UX Men has also been studied (*AAp 211*,346). The binary in the Hyades, V818 Tau, provides an example (*AJ 93*,1471) for studies of initial chemical compositions.

Spectroscopic orbits have been obtained by Popper (*ApJSup 71*,595) for 12 Algol-type binaries leading to absolute dimensions which can allow both comparison with evolutionary models and discrimination of mass transfer processes such as described by De Greve (*SpScRev 50*,127). Radial velocities were measured from the Na D lines for the cool star and photospheric lines at high dispersion for the primaries. Evidences were found of non-photospheric material in the hotter spectra of the longer period systems. Extensive study of Algol itself (*AJ 96*,326; *SpScRev 50*,358) produced a new model for this prototypical binary. Other Algols analyzed are 5 Cet (*ChAAp 13*,181), U Cep (*SpScRev 50*,261), U CrB (*SpScRev 50*,264), TT Hya (*AJ 95*,1204; *AJ 96*,755), RW Per (*AJ 95*,1828) and RS Vul (*SpScRev 50*,347). Procedures to estimate absolute dimensions in single-lined Algols were discussed by Garcia and Gimenez (*SpScRev 50*,341) by comparing results with double-line cases. The B-type semidetached binary BF Cen (*SpScRev 50*,346) is of special interest as a member of the open cluster NGC 3766. Studies of eclipsing binaries in open clusters define an important research area for understanding formation processes, ages, and distance scales for both binaries and clusters as emphasized by Milone and Schiller (*PASP 100*,1223) and Clausen and Gimenez (*10EurRegMeet*,p. 185) who compiled a catalogue of optical coincidences. Results were shown for DS And (*AJ 95*,1466) in NGC 752.

Popper (*AJ 95*,1242; *AJ 96*,1040; *AJ 100*,247) has also contributed a major revision of spectroscopic orbits and absolute parameters for 19 eclipsing binaries with CaII H & K in emission within this triennium. An important advance in the study of the evolutionary status of RS CVn-like stars became possible and the case of Z Her, with reverse mass ratio in a detached configuration, was included. Other cases studied belong to the short-period subgroup (*ApJ 319*,827; *JApA 10*,307) and RS CVn itself (*AAp 231*,375). A comparison with normal detached systems and evolutionary models has been carried out by Montesinos et al. (*MN 232*,361) and a contribution was made by Tout and Eggleton (*MN 231*,823) to explain "mass inversion" through tidal enhancement of stellar winds. Moreover, tides have been suggested by Glebocki and Stawikowski (*AAp 189*,199) as the cause of enhanced chromospheric activity.

New fundamental parameters for the interacting W Ser-type binaries SX Cas and RX Cas have been provided (*SpScRev 50*,179; *AAp 207*,37; *AAp 215*,272) by using photoelectric devices to obtain accurate spectroscopic orbits. Both systems were found to have semidetached configurations despite previous studies, and evidences of large amounts of transferred mass around the primaries were detected. The continuous flux distribution of the components of Bet Lyr has been determined (*10 EurRegMeet*,p. 301) using optical spectrophotometry and UV spectra. There were also obtained good-quality spectroscopic orbits for the pre-main sequence binary AK Sco (*AAp 219*,142) permitting discussion of the evolutionary status and level of synchronization of the components despite the non-eclipsing nature of the system and its intrinsic variability. Studies of BM Ori, a pre-main sequence binary with good absolute dimensions, show the cooler component as an oblate spheroid (*SovAL 15*,362) and demonstrate its T Tau nature (*SovA 32*,508).

Short-period non-contact binaries, such as BL Eri (*AJ 95*,894), DD Mon (*AJ*, *99*,1218) and RU UMi (*PASJ 40*,79), provided information about remnants of large amounts of mass loss from the systems. On the other hand, reverse Algols, wherein the more massive component fills its critical Roche lobe, were reviewed by Leung (*SpScRev 50*,279) who presented 7 candidate systems. Other studies of contact or near-contact binaries include the following: BX And (*MN 244*,328; *AJ 97*,1159), IU Aur (*ChAAp 12*,298), EE Aqr and RS Ind (*MN 232*,147), XZ Cep (*ATs 1538*), TV Mus (*MN 237*,447) with an extreme mass ratio and in deep contact, RZ Pyx (*MN 227*,481) and CX Vir (*MN 231*,297). Classical W UMa-type binaries are being analysed also by several groups to derive reliable absolute dimensions. The archetypical system 44i Boo has been studied (*AAp 211*,81) and U Per was revisited (*ApSpSc 146*,1) modelling light curve anomalies with spots. Further individual cases are: OO Aql (*ApJ 340*,458), AB And (*ApJ 335*,319), V523 Cas (*AJ 98*,2287), VW Cep (*AAp 218*,141), RW Com (*ApJ 319*,325), CC Com (*ApSpSc 141*,199), BW Dra (*ApSpSc 148*,289), SW Lac (*ChAAp 13*,350), V508 Oph (*AAp 231*,365), V566 Oph (*AAp 218*,152) and VZ Psc (*AJ 97*,532). A review of empirical data on masses, radii and temperatures for W UMa and related systems was given by Hilditch et al. (*MN 231*,341) leading to discussions of the evolutionary path from detached to semidetached and contact states by Hilditch (*SpScRev 50*,289)and by Sarna and Federova (*AAp 208*,111).

Evidences of binarity in RR Lyr- and Del Cep-type variables, such as S Mus (*AJ 99*, 353), have been studied by several authors. Popper (*AJ 95*,190) analyzed the cases of VZ CVn and AI Hya, early-F binaries with variable components; Del Cap seems to show intrinsic variations (*AJ 97*,499), and the eclipsing Bet Cep-type star 16 Lac has been revisited (*AA 38*,401). Global absolute parameters have been estimated in other groups of binaries. Dimensions for the Wolf-Rayet eclipsing binary CQ Cep have been obtained (*ApJ 351*,651; *SovA 32*,531) and the orbit of V444 Cyg determined (*AAp 226*,137). Further data on masses and evolution of Wolf-Rayet stars were reviewed by Shulte-Ladbeck (*AJ 97*,1471). Discussion on the evolutionary status of symbiotic stars has also been continued by Yudin (*ApSpSc 135*,143) and Nussbaumer and Vogel (*AAp 182*,51; *AAp 213*,137) using spectroscopic orbits as for TX CVn (*AJ 97*, 194) or eclipsing systems such as BF Cyg (*AJ 98*,1427; *AAp 227*, 422). Determination of orbital elements for Pop II binaries (*AAp 188*,39) has increased the search for eclipses, and the discovery of a new eclipsing AM Her system (*AAp 195*,L12 and L15) has renewed interest in direct estimation of fundamental parameters for the member white dwarfs. Observations of the eclipsing nova-like variable DW UMa (*ApJ 327*,248), the dwarf nova OY Car (*ApJ 341*,974), the dwarf binary V471 Tau (*AJ 96*,157) and spectrophotometry of EG-1 (*ApL 345*,L91) also provided important constraints. A new orbit has been obtained for the famous binary Cyg X-1 (*ApJ 321*,425) and absolute dimensions estimated from model atmospheres (*SovA 31*,419) for this system. Absolute magnitudes for cataclysmic variables are discussed by Warner (*MN 227*,23).

Studies about the physical meaning of orbital angular momentum in the formation and evolution of binary stars have continued. Some information may be revealed about the environment where binaries were formed as is indicated in the studies by Tohline and Christodoulou (*ApJ 325*,699) and Tohline (*HighAstr 8*,137). Angular momentum loss from rapidly rotating tidally-coupled components has been evaluated by van't Veer and Maceroni (*AAp 220*,128) and Quiroga and Vaz (*ApSpSc 146*,99) studied angular momenta for different types of systems.

Apsidal Motion and Tidal Evolution

The slow apsidal motion of DI Her has proved still to be of considerable interest. Conventional interpretations have been based on a misalignment between the rotational and orbital axes, as by Company et al.(*ApJ 335*,962) and Reisenberger and Guinan (*AJ 97*,216), or via a third body decreasing the orbital eccentricity as studied by Zakharov et al. (*ATs 1529*,13). AS Cam (*PASP 101*,925; *AJ 98*,1800) has also been found to show an anomalous apsidal motion rate in a closer configuration. The cause of the discrepancy between observations and theory remains an unsolved problem. Most recent observational evidences show that there is no significant misalignment, as suggested by tidal evolution, and the presence of undetected third bodies has little likelihood. Unconventional approaches, such as the nonsymmetric theory of gravity proposed by Moffat (*ApJ 287*,L77; *PhysRevD 39*,474)), are still not convincing in that revised expressions for apsidal motion explain the cases of DI Her and AS Cam but fail for other classical systems.

A list of 93 binaries showing apsidal motion and 197 candidates has been published by Hegedus (*BullCDS 35*,15). Individual systems for which apsidal motion studies have been done are the following: V889 Aql (*SovA 33*,41), HP Aur (*ApSpSc 165*,1), OX Cas (*ApSpSc 138*,361), EM Car (*AAp 213*,183), NY Cep (*AAp 231*,89), V477 Cyg (*ATs 1536*,23), V453 Cyg (*ATs 1537*,21), DI Her (*SovAL 13*,88), AI Hya (*APSpSc 155*,53), CO Lac (*ATs 1495*), Del Ori (*Obs 107*,205), V523 Sgr (*AJ 97*,842) and DR Vul (*SovA 32*,56). From a theoretical point of view, Hosokawa (*Vistas 31*,329) has shown tidal friction effects on apsidal motion to be negligible unless stellar viscosity is much larger than expected, and a simple analytical approach to the internal density distribution of MS stars has been proposed by Maslev and Nikolov (*ApSpSc 154*,281). A complete grid of theoretical models for the internal structure constants has been published by Claret and Gimenez (*AApSup 81*,1).

Revision of the theory of equilibrium tides in convective stars has been carried out by Zahn (*AAp 220*,112) providing improved equations of dynamical evolution. Application to the study of orbital circularization by Zahn and Bouchet (*AAp 223*,112) proved the importance of pre-main sequence phases. Moments of inertia of main sequence stars were given for composite-polytrope models by Rucinski (*AJ 95*,1895) and for standard evolutionary models by Claret and Gimenez (*AApSup 81*,37). Identification of eccentric orbits in tidally-circularized systems has been used by Mazeh (*AJ 99*,675) as a clue for disturbing third bodies and by Mathieu and Mazeh (*ApJ 326*,256) as a clock for age determinations in open cluster members through the cutoff period.

Concerning rotational synchronization, a purely hydrodynamical mechanism has been presented by Tassoul (*ApJ 322*,856) with large-scale meridional flow superposed on the motion around the rotation axes. Circularization under hydrodynamical spindown reproduces the observations of early-type binaries well as Tassoul (*ApJ 324*,L71) shows but a reinterpretation of Zahn's theory leading to a more efficient rate of synchronization in early-type stars has also been done by Goldreich and Nicholson (*ApJ 342*,1079). Pre-main sequence tidal interaction has been used by Habets and Zwaan (*AAp 211*,56) to explain some cases of non-synchronous rotation in circular orbits. Further observational data are given for Algols by Tan (*AASin 30*,135) and Huisong (*SpScRev 50*,368) and for RS CVn-type systems by Tan and Liu (*BeijingColl*, p. 55). Studies have been published by Abt (*BeijingColl*,p. 1) about effects of tidal braking in the formation of Am stars; by Fekel and Eitter (*AJ 97*,1139) concerning synchronization in long- period active binaries; by Applegate (*ApJ 337*,865) with regard to effects of magnetic activity in tidal synchronization;

by Alexander (*MN 227*,843; *MN 235*, 1367) regarding effects of tidal resonances in the equations of motion; and by Rieutord and Bonazzola (*MN 227*,295) on the tidal heating of low-mass stars.

Distortions of close binaries due to rotation and tides were reviewed by Kopal in his book "*The Roche Problem*" and Zafiropoulos has studied the effects of tidal lag and oblique rotation (*ApSpSc 136*,149; *ApSpSc 137*,139; *ApSpSc 136*,211). Further studies include effects on equilibrium structure by Mohan et al. (*ApSpSc* 163,*23)*, on tidal fluxes and evolution by Dolginov and Smel'chakova (*ApSpSc 159*,133), and on the effect of rotation on the dynamical tide and surface brightness by Rocca (*AAp 213*,114). Finally, several papers have been dedicated by Ardakani and Sobouti (*AAp 227*,71), by Eriguchi (*AAp 229*,457), and by Sobouti and Ardakani (*Vistas 31*,351) to analyzing the excitation of stellar oscillations by tidal processes.

Atmospheric Parameters

New linear and non-linearized limb-darkening coefficients have been computed by Claret and Gimenez (*AAp 230*,412) for late-type stars using model atmospheres There was also shown the effect of irradiation by a hot companion. Extensive work concerning gravity darkening has continued. Major contributions have been made by Kitamura and Nakamura (*ApSpSc 145*,117; *SpScRev 50*,353; *AnnTokyo 21*,387; *AnnTokyo 22*,31) for W UMa-type binaries, detached main sequence components, Roche-lobe filling members of semi-detached binaries, and early-type contact systems, respectively. The W UMa-type systems have also been discussed theoretically by Sarna (*AAp 224*,98). Concerning the reflection effect, a recent review on the accuracy and efficiency of calculations in binaries by Wilson (*ApJ 356*,613) provides new insight and computational methods for geometrical aspects and bolometric energy exchange. Characteristics of irradiated stellar atmospheres were studied by Vaz and Norlund (*AAp 228*,231) in the non-grey case with convection so as to show the effects on the spectrum of the illuminated star and values of the bolometric reflection albedo. The case of hot irradiating components, that of classical Algols, has been studied by Gimenez and Claret (*SpScRev 50*,343). Effects of irradiation on envelope structures have also been studied: photospheric flows in non-synchronous early-type stars by Tassoul and Tassoul (*MN 232*,481) and the effects on radial velocities from the photospheric motions by Kopal (*ApSpSc 144*, 557).

Direct measurement of metal abundances in detached binaries has been commented on before. The primary stars of Algol binaries have also been studied with low-noise Reticon observations of visible or near infrared lines by Tomkin and Lambert (*MN 241*,777) or of UV spectra by Cugier (*AAp 214*,168). A moderate depletion of C and an enhancement of N was evidenced in the work of Cugier and Hardorp (*AAp 202*,101). Interpretations were made under several evolutionary scenarios involving C-poor mass transfer and mixing processes by De Greve and Cugier (*AAp 211*,356). Reviews on atmospheric evidences of evolution in close binaries have appeared from Sahade (*IAUColl 108*,199 & 206), Plavec (*ESA SP-281*,221) and Leushin (*SovA 32*,291). Studies of CNO abundances for symbiotic stars support their modelling as binaries as in the work by Nussbaumer et al. (*AAp 198*,179) and metal contents have also been estimated for Mu Sgr by Leushin and Topil'skaya (*Ap 28*,213 & 329), and for TX Leo and V380 Cyg by Leushin (*Ap 30*,229).

5. Origin of Binaries (Richard H. Durisen and Robert D. Mathieu)

There have been several recent reviews of observations pertinent to the question of binary origin in star forming regions (SFR's) (Reipurth in *Formation and Evolution of Low-Mass Stars*; Mathieu in *HighAstr 8*,111; Zinnecker in *Low-Mass Star Formation and Pre-Main Sequence Objects*). Reviews which relate the data to origin theories include Shu et al. (*AnnRevAAp 25*,23), Boss (*CommAp 12*,169; in *nteracting Binary Stars*), and Bodenheimer et al. (in *Protostars and Planets III (PPIII)*).

Binaries of all periods have been found among pre-main sequence (PMS) stars of all ages, including some near the stellar birthline. Binary formation evidently can occur very early in the evolution of a star. The count of published PMS spectroscopic binary orbits now stands at 11 (Popper *ApJ 313*,L81; de la Reza et al. in *New Insights in Astrophysics*; Marschall and Mathieu *AJ 96*,1956; Andersen et al. *AAp 219*,142; Mathieu et al. *AJ 98*,987; Mathieu et al. *AJ* in press; Reipurth et al. *AAp* in press). The naked T Tau binary frequency for periods less than 100 days is indistinguishable from that found among main sequence binaries of similar masses. Surprisingly, few spectroscopic binaries have been found among the classical T Tau stars, although V4046 Sgr, AK Sco, and GW Ori have evidence for circumbinary material. All PMS binaries with orbital periods less than 4 days have circular orbits, shorter than a similar transition period of 11 days among main sequence stars. Double-line binaries provide a check of the mass and age calibrations of PMS evolutionary tracks. They are in good agreement for the eclipsing binary EK Cep but have been called into question for younger binaries such as P1540 and 162814-2427. Among massive stars, Bossi et al. (*AAp 222*,117) have suggested that The1 Ori A may be a PMS system.

Equally great progress has been made in the past few years for spatially resolvable PMS binaries. Lunar occultation observations at the K-bandpass have discovered 9 pairs among 31 PMS stars (Simon et al. *ApJ 320*,344; Chen et al. *ApJ 357*,224). The detection frequency is comparable to the main sequence detection frequency in this period regime, but account has not yet been taken of the differing observational biases. The observed secondary/primary flux ratios are roughly uniformly distributed between 0.1 and 1, but conversions to mass ratios are complicated by likely disk contributions at 2 micrometers.

Speckle observations, especially in the near-IR, have discovered many close PMS pairs: e.g., SVS20, (Eiroa et al. *AAp 179*,171 and Eiroa and Leinert *AAp 188*,46); DoAr24E [alias Elias 22] and Glass I, (Chelli et al. *AAp 207*,46); Sz 30, (Reipurth's review); Haro 6-10, (Leinert and Haas *ApJ 342*,L39); DK Tau, (Weintraub et al. *BAAS 21*,715); XZ Tau, (Haas et al. *AAp 230*,L1); MWC 863 [alias Elias 49], (Zinnecker's review). Several of these "infrared companions" are particularly interesting in that the optically fainter or invisible companions (e.g., Glass I, Haro 6-10, XZ Tau) become brighter at near-IR wavelengths and are bolometrically more luminous than their primaries.

The existence of visual binaries among T Tauri stars has been known since their discovery. Some recent additions are reported in Walter et al. (*AJ 96*,297). Several systematic optical and near-IR imaging surveys are underway (Reipurth's review). Moneti and Zinnecker (*AAp* in press) have completed a near-IR imaging study of 9 PMS pairs. In nearly all cases the brighter component at the K-bandpass (and in the optical) is the redder at (J-K), from which they conclude that the ratio of disk to stellar luminosity increases with stellar luminosity. With the additional assumption of coeval formation, they argue further that more massive binary companions take a longer time to shed their circumbinary material. Beckwith et al. (*AJ 99*,924; see also Beckwith and Sargent in *PPIII*) have made 1.3mm observations of 18 PMS binaries, most of which have projected separations between 1 and 1000 AU. They find detectable disk masses (greater than 0.01 solar) only for projected separations greater than about 100 AU, the typical value deduced for the outer radii of circumstellar PMS disks. This suggests that companions embedded in such disks act to reduce the total disk mass.

The recent observational work is consistent with the following notion. Binaries form in eccentric orbits with a main-sequence-like frequency and distribution of orbit separations during the earliest stages of star formation, probably during the protostellar phase.

Fragmentation during cloud core collapse (see Boss reviews and Monaghan and

Lattanzio *ApJ* in press) remains the only mechanism explicitly demonstrated to be capable of producing binary stars with a wide range of mass ratios, separations, and eccentricities, as well as producing hierarchical multiple systems. Fission calculations with an expanded range of physical conditions, including a variety of polytropic equations of state (Williams and Tohline *ApJ 334*,449) and a realistic protostellar core simulation (Boss *ApJ 346*,336), continue to produce only spiral arm ejection of mass and angular momentum - not binary stars - even after repeated episodes of fission. Capture, which is enhanced by the presence of circumstellar disks (Larson in *Physical Processes in Fragmentation and Star Formation(PPFSF)*), can only be significant in regions of much higher stellar density than is typical of galactic SFR's.

Fragmentation during collapse only works, however, if the inital cloud core is not strongly centrally concentrated (Boss *ApJ 319*,149). If rotating cores in low-mass SFR's form and approach collapse through quiescent ambipolar diffusion (e.g., Lizano and Shu *ApJ 342*,834), fragmentation during collapse does not occur. A star with a massive circumstellar disk forms instead (Durisen et al. *ApJ 345*,959; see also Bodenheimer et al. *ApJ 355*,651, Lin and Pringle *ApJ 358*,515). So the debate about fragmentation becomes one about the initial conditions for collapse and the nature of dense structures in molecular clouds. Pringle (*MN 239*,361) has suggested that relatively uniform cores not formed by ambipolar diffusion are triggered into collapse and binary fragmentation by cloud collisions. In *PPFSF*, Scalo also challenges the view that cloud cores form quiescently by ambipolar diffusion, and Heyer (*ApJ 324*,311) has invoked core collisions to explain some properties of the cores in the Taurus complex. Decisive information should come from more and better resolved observations of protostellar binaries (Wooten *ApJ 337*,858) and of the structures within cloud cores of both low and high-mass SFR's (e.g., Mezger et al. *AAp 191*,44; Benson and Myers *ApJSup 71*,89). More theoretical work on cloud collisions (Lattanzio and Henriksen *MN 232*,565), on generalized cloud core geometries (Rouleau and Bastien *ApJ 355*,172), and on fragmentation criteria (Hachisu et al. *ApJSup 66*,315) would be helpful.

The combined evidence for disks in protostars has become overwhelming (*PPIII*). In one of the more intriguing recent theoretical developments, Adams et al. (*ApJ 347*,959) have shown by linear analysis that massive Keplerian disks are subject to dynamic, global, eccentric one-armed spiral instabilities. The instability mechanism, called "sling" amplification, involves a four-wave feedback loop of refracted and reflected long/short and leading/trailing spiral waves. The star and disk suffer exponentially growing displacements in opposite directions about the center of mass. For typical conditions, these instabilities occur only when disks contain more than about 25% of the system mass (Shu et al. *ApJ 358*,495). Nonlinear calculations are needed to determine whether a star/disk system could be turned into a binary by this mechanism. If fission calculations are any guide, however, gravitational torques in a nonlinear spiral instability would probably tend to suppress binary formation.

6. Close Binary Interactions and their Consequences

A. ENERGY AND MASS TRANSFER FOR CONTACT SYSTEMS (Kam-Ching Leung)

The structure of contact CB's has been a major astrophysical problem for decades. For early-type systems, the observed mass ratios range from about 0.25 to about 1.0. For late-type systems, light curves have similar eclipse depths and mass ratios are usually about 0.5 (or inversely 2.0). This implies that there must be an energy transfer between the components. Thus, the stars have to be in contact. However, the mass and energy transfers cannot be observed directly. Usually the "observed energy tranfer" involves some assumed parameters. Attempts have been made to measure the energy and mass tranfers as, e.g., by Hilditch et al. (*MN 231*,341). These suggestions may lead to useful measureable quantities.

The difficulty in constructing contact models lies in understanding the transfer mechanism(s). In the late 1960's, Lucy made an early attempt at solving this problem. About a decade later, Shu and his associates tackled the problem by an entirely different approach. Subsequently, it was generally agreed that both theories had their shares of difficulties. Since the mid-1970's Hazlehurst and associates have been working on the same problem. A very good summary on recent developments on energy transfer in contact systems may be found in Sinjab et al. (*MN 224*,619). These authors performed a numerical simulation on the original idea of Hazlehurst (*AAp 145*,25) that energy is transferred in the deep adiabatic layers. They found undesirable quantitative results and concluded that more tests have to be performed.

Kahler (*AAp 209*,67) proposed a new approach. He argued that hydrostatic equilibrium should be the dominant consideration. This model was strongly criticized by Hazlehurst (*Obs 109*,91).

Zhou and Leung (*ApJ 335*,271) proved that a static model is not possible and that the development of circumfluence/circulation is inevitable for contact systems. The advantage of this approach is that it can be applied to both early-and late-type systems. They attempted to explain the asymmetrical O'Connell Effect in contact binary light curves in terms of the Coriolis effect on the circulation. However, numerical simulation is needed to demonstrate whether such steady circulation can be achieved.

B. EVOLUTION ABOVE THE MAIN SEQUENCE (Edwin Budding)

The first clear and well known stage after one of a pair of main sequence stars expands and specifically binary interactive effects occur is that of the Algol configuration. This was the first example to test binary evolution modellers about 25 years ago, and even then gave good promise of being on the right track, with the salient result of a fairly good explanation of the observed overluminosities of the secondary components. IAU Colloquium No. 107, held in Victoria just after the last General Assembly, gave an excellent opportunity to review these last 25 years of research.

Though at times reaching out beyond the confines of its deceptively short title, this conference was an important milestone for binary star specialists, from which they could (i) assess, in detail, the extent of shared understanding on that modern paradigm of stellar astrophysics - the "Roche Lobe Overflow" (RLOF) mechanism; (ii) determine what new features have appeared in recent studies which reveal still existing areas of uncertainty, or ignorance; and (iii) receive good pointers towards future research. Conspicuous in the first area was the need to be aware of those features of interactive binary evolution which are not explained by classical, conservative RLOF. Noticeable in the second area were the interesting contributions of photopolarimetry and high-resolution CCD photometry. The mechanics of ejected matter, for which the binary stellar environment presents a special context, also continue to give worthy challenges to theory, aided by updated spectrometric surveillance. The common assent sensed in areas (i) and (ii) becomes, expectably, less clear in the third area. The fuzzy edges of the definition of an Algol system become more troublesome when one tries to integrate the subject more thoroughly into the full range of stars.

Thus, Bet Lyr continues to cast its baffling light patterns into our telescopes. Nowadays most specialists would like to see it as an example of a somewhat aberrant, overactive, "fast" or "Serpentid" class of Algols. But just where and why is the dividing line? Why do some Algol-like binaries have thick disks and show such exotic behaviour, particularly in the UV? Bet Lyr, in fact, stops being an eclipsing binary shortward of 120nm. In reporting this result from Voyager UVS data, Polidan (*SpScRev 50*,85) also showed remarkable time-dependent enhancements in the 95.5nm flux, reminiscent of the development of "outbursts" in cataclysmic variables. The rewards of more extended coverage, even from a telescope as small as 25-cm, were demonstrated by Guinan (*SpScRev 50*,35), presenting evidence which included that from the small APT (Automatic Photometric Telescope) on Mt. Hopkins, who reported distinct patterns in the light curve of Bet Lyr on a nearly 275-day cycle time such that, when the eclipse minima are deeper, the system as a whole is less bright by ~0.1 mag in the red region. Comparable, but less extensive, data on W Ser was also found to indicate some quasi-periodic photometric irregularities - all of which points up the need for a fully concerted, multi- facility study on the behaviour of thick disks associated with non-degenerate stars. KX And is a case-study of this type in the recent work by Stefl et al. (*BAC 41*,29).

There has been renewed interest in whether barium stars also result from a variation of the Algol story, if it be true that they always have a white dwarf as a fairly wide companion. Hakkila's (*AJ 98*,699) comprehensive review of Ba stars points to Am stars as promising candidates for their main sequence progenitors, but the trip from Am to Ba state is still not clear. What kind of interactive stage would be passed through *en route* is one puzzle that occurs if RLOF is involved. That the present Ba stars were the original secondaries may be another (for then the expected abundance peculiarities of the transferred material should have been erased by convection as has been indicated by Lambert. Perhaps a wind, rather than RLOF, can better account for the data as Boffin and Jorissen (*AAp 205*,155) suggest.

A convective fast stage in the evolutionary passage from a post-main sequence primary to an Algol has for a long time been thought to be inevitable. Indeed, so drastic were initial "dynamic time scale" effects visualized for Case B (and C) transferers that it was difficult to see how the innocuous-seeming final configuration could be achieved. Moreover, while the swell-up, common-envelope, and spiral-in scenario was problematical for Algols, it was good for other things, i.e., some planetary nebulae, symbiotic stars and cataclysmic variables. The important finding that certain RS CVn stars show the more evolved primary to be less massive than the secondary demonstrates the need to take into account non-RLOF mass loss processes for interactive binary evolution scenarios *ab initio*. Tout and Eggleton (*ApJ 334*,357) have emphasized this idea. The concept has opened the way for investigations such as Kuin and Ahmad's (*ApJ 344*,856) modelling of Alfven wave-driven winds in Zet Aur binaries and the search for the critical factors influencing mass loss.

The proceedings of IAU Colloquium No. 103 on symbiotic stars contained many articles showing the importance of non-RLOF mass loss in interactive binary evolution. Multi-wavelength observations, reviewed by Kenyon (*ApSpScLib 145*,11), are incisive for the analysis: for example, the detailed work on RX Pup, from the VLA observations of Kafatos and Michalitsianos (*ApSpScLib 145*,245) to the IR and optical data covered by Allen and Wright (*ApSpScLib 145*,249). Strong pulsational winds from the cool giant interact with hot radiative outflow from the dwarf. Where else can matter go but into bipolar streams pouring away from the orbital plane? We might thus approach a view about those bipolar planetary nebulae with binary central stars, which may well descend from such a configuration. More recently, however, Hollis et al. (*ApJ 337*,514), probing still deeper into the circumbinary cloud of RX Pup with the VLA at 2-cm, find only one lobe to the putative ejecta. The observed features may just be part of some temporary phase of activity and more continuous high resolution radio astronomy seems called for. More generally, it is anticipated that space-borne large telescopes will have an exciting task in revealing details of such mechanisms.

The role of binarity in planetary nebula formation is a natural hypothesis in the scheme of Livio and Soker (*ApJ 329*,764): it allows an angular momentum parameter for the wind of the cool giant progenitor, which can then unify the

https://doi.org/10.1017/S0251107X00010300 Published online by Cambridge University Press

interpretation of a range of different PN morphological types. Some PN's are observed to have binary central stars but, for those that don't, one can also dispose of the companion in manners suggested by Soker (*ApJ 340*,927), and observations suggest coalescence can occur during the common envelope stage if the discoveries by Mendez et al. (*AAp 197*,L25) can be generalized. A gamut of possible evolutionary scenarios, ranging from conventional Algols through the drastic interactors which can produce PN's with various central configurations, was nicely reviewed by Eggleton (cf. ed. Mennessier and Omont, Editions Frontieres, p. 513) at the 1989 Montpelier Colloquium. There are still problems to explain in the varieties of morphologies of the nebulae - e.g., the ansae studied by Soker (*AJ 99*,1869) - and, though interactive binary models can clearly give rise to many different types of end result, the role of the interstellar medium itself should not be lost sight of Bond and Livio (*ApJ 355*,568) have emphasized this matter. This is also a subject where much basic observational work is still required. The Montpelier conference article of Jurcsik, for example, showed that even with the 8th mag central star IN Com we cannot be sure whether we have a binary or a triple object, or what it is that gives rise to the photometric variations.

There has emerged in recent years a growing interest in the incidence of binarity among Cepheids - long treated as essentially single variables. Among the issues raised are that binaries provide good information about basic stellar properties such as masses and luminosities - important quantities to know to tie down models. But at a time when more and more Baade-Wesselink type analyses are appearing, the negligence of binarity on the colour curve is a potentially serious source of error. Hence, studies such as those of Szabados (*PASP 100*,589; *MN 242*,285) are of potentially far-reaching interest, not only in relation to the foregoing, but also regarding the dynamics of the interactions between a pulsating star and an orbiting companion. All this has been emphasized by Alexander (*MN227*,843), Beiki and Sobouti (*AAp 227*,71), and Eriguchi (*AAp 229*,457).

C. THE NOVA PHENOMENON IN CLOSE BINARIES (G. Shaviv and R. H. Koch)

The basic problem of the evolution of novae was and still is the question of *hibernation*. Hibernation was invented by Shara, Livio, Moffat and Orio as a solution to the problem of "unseen" nova.

The problem in the evolution of novae came about in the following way. Bath and Shaviv (*MN 183*,515) made a prediction of the total number of novae that should be observed in the Milky Way Galaxy. Their prediction was based on the number of novae observed in M31, the number observed in the solar neighborhood, and the adopted theory for the cause of the classical nova outburst. Patterson (*ApJSup 54*,443) compared the observed numbers with the predictions of Bath and Shaviv and found far fewer novae than predicted. This result of Patterson gave rise to much of what follows.

The basic assumption made at that time in the simulation of thermonuclear runaways (cf. Starrfield in *Classical Novae* p. 39) was that the mass of the envelope was in place at the start of the calculation. This particular assumption was removed by Prialnik et al. (*ApJ 257*,312) in a calculation which included the accretion process. Hence, the envelope was allowed to grow in time until the moment of outburst.

The results of these calculations were, roughly, that there is an upper limit (of the order of few*10^{-9} $M_{\odot}$/yr) to the mass accretion rate for which a thermonuclear runaway occurs. If the accretion rate is higher, the star expands to become a red giant and does not develop a runaway. On the other hand, a lower accretion rate will always end with a runaway but the lower accretion rate will need a longer time to develop it. If the counts of Bath and Shaviv are correct, the correct numbers should be about 10^{-8} (in the aforesaid units). But as was pointed out by Patterson, the luminosity of the nova accreting at this high accretion rate should be sufficiently high so as to be seen in his survey. The observed number, however, is significantly smaller than expected.

The basic idea of hibernation is that the accretion rate is not constant in time over the 10^5 years that the White Dwarf accretes mass. Very beautiful observations of old novae carried out by Shara show that practically all old nova (ages vary from a few to hundreds of years) are faint, thus indicating a low accretion rate. On the other hand, observation immediately (say, up to a few months) after outburst show that the luminosity of a system is then the same as the luminosity before outburst.

The authors of the hibernation theory propose that soon after an outburst the White Dwarf is hot and the UV radiation from its surface heats the surface of the secondary and induces a high mass loss rate and hence a high accretion rate. After cooling, this process stops and with it the accretion rate dwindles to very low values, so low that the quiet nova is hardly observed. While this explantion nicely solves the problem raised by Patterson vis-a-vis the predictions of Bath and Shaviv, it generates a new problem: why the accretion rate decreases with time or, to put it differently, why the natural rate of accretion is low and increases just before outburst? This query may be misleading. Note that when the accretion rate is low, the interval between outbursts is very long. On the other hand, "almost" as soon as the accretion rate becomes as high as 10^{-8}, the nova suffers outburst (because the time needed for accumulating the envelope at this rate is quite short). Thus, one could also propose that the natural state is a low accretion rate but, if for some reason the accretion rate increases to the above high value, an outburst follows. The source of the name *hibernation* is the idea that the nova is dormant for a long time and only rises to outburst when it "awakens". The above description forms the basic ideas of the hibernation theory. Recently several novel variants of the theory were proposed, none of them more credible than the original one.

One may enumerate many theoretical problems with all variants of hibernation, e.g., how does it happen that the accretion rate changes? what are the long term consequences of such a theory? why does the accretion rate increase? From the observational point of view, some old novae are "peculiar" so that drawing a general conclusion may not be justified. In view of the above difficulties, the theory has not yet gained wide support but it is the only theory we have. Extensive theoretical work is going on but the most important matter is that deep surveys of certain well-selected regions in the sky are needed to establish *observationally* that the many novae Bath and Shaviv spoke about are faint and not bright!

A considerable number of novae have been discovered in the last triennium and a discussion concerning them appears, as usual, in the Report of Commission 27. There has also been a substantial amount of observational effort and theoretical interpretation of old novae but this material is too voluminous to be discussed here in detail.

Perhaps the most remakable recent contribution concerns V1500 Cyg = N Cyg1975. After the early observational interest in this object and the final decision concerning the length of its period, interest seemed to wane but resurged quickly after the last General Assembly. For instance, as recently as 1987 Kaluzny and Semeniuk (*AA 37*,349) were commenting on the stability of the period but Pavlenko (*IzvKrim 79*,103) now claims variability somewhat greater than 10^{-6} days. The discovery of circular polarization from the ex-nova by Stockman et al. (*ApJ 332*,282) and the contemporaneous spectroscopy and photometry by Chlebowski and Kaluzny (*ApJ 332*,287) represent the earliest (in a stellar evolutionary sense) discovery of a polar ever made. Since the mass of the white dwarf is now known, at to be at least $0.9M_\odot$, from the work of Horne and Schneider (*ApJ 343*,888), the interest in the evolution of this relatively high-mass star increased very much. The interactions with the lower-mass companion - in terms of its irradiation by the white dwarf, magnetically-guided mass transfer, and magnetic torques exerted in the system - are bound to attract more attention to the star. It is unfortunate that the object is so faint but it can be expected to command a reasonable amount of large-telescope time from now on.

D. NEUTRON STAR AND BLACK HOLE BINARIES (R.F. Webbink)

The supposed origin of single millisecond pulsars in binary systems received stunning support with the discovery of the eclipsing binary pulsar PSR 1957+20 by Fruchter et al. (*IAUC 4617*). The sub-stellar mass companion is being ablated by irradiation from the pulsar, a process variously estimated to require at most a few 100 Myr to consume the companion. Phinney et al. (*Nat 333*,832), Kluzniak et al. (*Nat 334*,225), Ruderman, Shaham, and Tavani (*ApJ 336*,507), Ruderman et al. (*ApJ 343*,292), and Cheng (*ApJ 339*,291) have all explored physical mechanisms for the ablation process.

The discovery within the past triennium of an astonishing number of millisecond pulsars in globular clusters has prompted renewed interest in capture mechanisms for the formation of neutron star binaries in dense stellar systems and critical re-examination of the putative descent of millisecond pulsars from low-mass X-ray binaries. Verbunt, Lewin, and van Paradijs (*MN 241*,51) found that the apportionment of millisecond pulsars among globular clusters indeed favors those clusters expected theoretically to have high capture frequencies. Nevertheless, a significant fraction of the globular cluster pulsars are apparently single, prompting Romani, Kulkarni, and Blandford (*Nat 329*,309) and Rappaport, Putney, and Verbunt (*ApJ 345*,210) to examine the possibility that their binary progenitors were disrupted by encounters with other stars in the clusters. The discovery of a short-period eclipsing pulsar in Terzan 5 (Lyne et al. *IAUC 4974*) now suggests a fate like that of PSR 1957+20. Kulkarni and Narayan (*ApJ 335*,755) have pointed out that the number of binary pulsars of short orbital period in globular clusters is higher by at least a factor of 100 than expected from the number of X-ray binaries in globular clusters. Coté and Pylyser (*AAp 218*,131) find a much smaller discrepancy and suggest that evaporation of the secondary may partially resolve the discrepancy. Grindlay and Bailyn (*Nat 336*,48) suggest that such ablation, immediately following creation of a pulsar by accretion-induced collapse, could circumvent the low-mass X-ray binary stage.

Several evolutionary studies of unusually broad scope have recently appeared concerning the origins of binaries with compact components. Dewey and Cordes (*ApJ 321*,780) constructed quite elaborate models of the formation of neutron stars in a population of binary systems with massive (8-20 solar mass) primaries and with realistic distributions of initial masses and orbital periods. These models incorporated not only effects of mass transfer and mass loss during normal mass exchange, but also of supernova explosions on orbital dynamics and on the secondary star, in an attempt to understand pulsar kinematics. They conclude, however, that binary evolution cannot account for the high space velocities characteristic of pulsars and that asyummetric supernovae are required. Lipunov and Postnov (*ApSpSc 145*,1) constructed a Monte Carlo simulation of the evolution of a very large number of low and intermediate-mass binaries through to the X-ray stage. Meurs and van den Heuvel (*AAp 226*,88) also constructed very detailed models for the distribution of massive X-ray binaries and Wolf-Rayet binaries with compact components. They find that they can reproduce the observed frequencies of both massive X-ray and Wolf-Rayet binaries with normal companions, provided that the fraction of exchanged matter lost from their progenitors does not exceed one-half. They also deduce a frequency of Wolf-Rayet binaries with compact companions which is significantly smaller than previous predictions.

Some noteworthy studies of the secular evolution of low-mass X-ray binaries have also appeared: e.g., Rappaport et al. (*ApJ 322*,842); Tutukov et al. (*PisAZh 13*, 780; Fedorova and Ergma (*ApSpSc 151*,125); Pylyser and Savonije (*AAp 191*,57 and *AAp 208*, 52). Several of these are concerned especially with the 685-sec system 4U 1820-30 in the globular cluster NGC 6624.

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