27. VARIABLE STARS (ÉTOILES VARIABLES)

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1. INTRODUCTION (J. Smak)

The contents and format of this Report was a subject of extensive consultations with all Commission Members and, in particular, with the Members of its Organizing Committee. Following the opinion expressed by the majority of Members, it has been decided that the Report should consist of a series of reviews covering all organizational problems and selected research areas. The Authors had freedom of choice between:

A. conventional presentation, with an emphasis on completeness of the survey and references, as it was the custom until now, and

B. critical review, or an essay, with an emphasis on the most important and prospective aspects and trends.

An effort was also made to avoid unnecessary duplication of work and, as a result, certain topics have been left entirely for other Commissions.

The complete list of Sections and Authors was published in I.B.V.S. No. 1448 to enable all active workers in the field to send their reprints, preprints, and other relevant information to the respective Authors.

During the period under review the following meetings took place on topics which are entirely, or at least partly, within the area of Commission 27:

IAU Symposium No. 75, Star Formation, Geneva (Switzerland), 6-10 September 1976.

IAU Symposium No. 80, The Hertzsprung-Russell Diagram, Washington, D.C. (U.S.A.), 2-5 November 1977.

IAU Symposium No. 83, Mass-Loss and Evolution of O-type Stars, Qualicum Beach (Canada), 5-9 June 1978.

IAU Colloquium No. 42, The Interaction of Variable Stars with their Environment, Bamberg (F.R.G.), 6-9 September 1977.

IAU Colloquium No. 46, Changing Trends in Variable Stars Research, Hamilton (New Zealand), 27 November - 1 December 1978.

IAU Colloquium No. 47, Spectral Classification of the Future, Vatican City State, 11-15 July 1978.

Conference on Novae and Related Stars, Paris (France), 7-9 September 1976.

Several excellent review articles covering the subject of variable stars have been published in "Annual Review of Astronomy and Astrophysics" and other similar publications. The extremaly useful role of "Astronomy and Astrophysics Abstracts" could hardly be overestimated. Our Commission's "Information Bulletin on Variable Stars" continues its important service.

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2. ARCHIVES OF UNPUBLISHED OBSERVATIONS (M. Breger)

The Archives of Unpublished Photoelectric Observations of Variable Stars was created to provide two permanent archives, one in Great Britain and another one in the Soviet Union for Socialist countries. The Archives can replace lengthy and expensive tables in scientific publications by a single reference to the archival file number. Furthermore, many observations are never used for scientific publications, and the Archives could make such observations available to other astronomers at a time when they might become very important.

In 1977, Dr. W.S. Fitch resigned as Coordinator of the Archives after many years of active service and was succeeded by Dr. M. Breger. At present, the Archives contain 59 assigned file numbers, of which the first 43 were previously described.

Astronomers who wish to obtain unpublished photoelectric measurements on variable stars may do so by requesting at, cost, whole files (not partial files) from either

Mrs. E. Lake, Librarian
Royal Astronomical Society
Burlington House
London, W1V ONL, Great Britain

or

Dr. E. Makarenko
Odessa Astronomical Observatory
Shevchenko Park
Odessa 270014 U.S.S.R.

Astronomers who wish to submit unpublished photoelectric observations of variable stars to the Archives, should submit two copies as well as a brief descriptive cover sheet to the Coordinator (address listed below). Alternatively, one of the two copies should be sent directly to Dr. Makarenko (U.S.S.R.). The Coordinator will assign file numbers and forward the observations to London (and Odessa, if necessary). New files must be printed or hand-written in black ink. The printed part should be no larger than 8.5 by 11 inches (21.6 by 28 cm). If a new file number is required for scientific publications (in place of extensive tables of measurements), the file number can be assigned by the Coordinator before receipt of the actual measurements.
The address is:

Dr. M. Breger
Department of Astronomy
University of Texas
Austin, TX 78712 U.S.A.

The new acquisitions are files IAU (27). RAS-

44. uvby measurements of WW Aur by Etzel.
45. UBV measurements of RU UMi by Hogg.
46. BV measurements of V1500 Cyg (Nova Cyg 1975) by Armbruster, Blitzstein, Hull and Koch.
47. UBV measurements of HX Ara by Duerbeck and Walter.
48. uvbyRI, Hα measurements of U Cep by Olson.
49. UBV measurements of TU Hor by Duerbeck.
50. BV measurements of EE Peg and S Equ by Catalano and Rodono.

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51. BV measurements of KO Aql by Blanco and Cristaldi.
52. ubvy measurements of HR 3413 = HD 73340 made by Heck and Manfroid and submitted by Renson.
53. Photometric observations of TT Ari by Duerbeck (still in preparation).
54. Photometric observations of AH Tau by Duerbeck (still in preparation).
55. ubvy magnitude differences between HR 3413 and HR 3440 by Renson and Sterken.
56. Photoelectric magnitude differences between HD 148898 (Omega Oph) and HD 148211 by Renson and Maitzen.
57. Photoelectric observations of HD 125248, HD 134793 and HD 184905 by Blanco, Catalano and Strazzulla.
58. B measurements of 14 Aur relative to 18 Aur made by Fitch and Wiśniewski.
59. Photoelectric photometry of 7 Ap stars: HD 59256, 66255, 66605, 83368, 83625, 94660 and 96616 made by Manfroid.

3. GENERAL CATALOGUE OF VARIABLE STARS (M.S. Frolov and P.N. Kholopov)

The Moscow team headed by Prof. B.V. Kukarkin and Dr. P.N. Kholopov continued accumulating all the data on variable stars. The Third Supplement to the third edition of the General Catalogue of Variable Stars, containing information on 699 variable stars designated in 1974-1975 and improved information on 3923 previously designated variable stars was published. The Second Special Supplement to the third edition of the General Catalogue of Variable Stars, containing the list of 3186 stars arranged in the order of right ascensions for the equinox 1950.0 was prepared and was published in the Special supplement to the bulletin "Variable Stars", Moscow, 1976.

The 61st, 62nd, and 63rd Name-Lists of Variable Stars were prepared and were published in IBVS No. 1068, 1248, and 1414 correspondingly. These Name-Lists contained the data on 200, 1045, and 313 objects, respectively.

Now the work on preparing for print the New Catalogue of suspected variable stars (one of the volumes of the Fourth edition of GCVS) is nearly finished.

4. CEPHEIDS (R.S. Stobie)

A. Introduction

This essay will attempt to outline the progress and major areas of development in the field of cepheid variable stars over the last three years. The list of references is not comprehensive and for a more complete list the reader is referred to Astronomy and Astrophysics Abstracts.

During the relevant period two reviews have been published on the observational aspects of cepheids, one by Pel (Conference on Current Problems in Stellar Pulsation Instabilities) and the second by Stobie (IAU Coll. 29), the latter having special reference to multiperiodic phenomena in cepheids.

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B. Multicolour photometry of galactic population I cepheids

In what must rank as one of the finest contributions to the observational study of cepheids, Pel (AA Sup 24, 413) has published Walraven five-colour photometry for about 150 cepheids in the Southern Milky Way. The quantity and quality of this data is outstanding and must represent the most extensive, uniform, high accuracy body of data ever obtained on cepheids. Lub and Pel (AA 54, 137) have discussed the properties of the Walraven system and the data have been analysed by Pel (AA 62, 75) and by Pel and Lub (IAU Symp 80, 229). It is shown that there exists a narrow intrinsic cepheid locus in the (V-B), (B-L) diagram. Using this locus, colour excesses are determined for 156 cepheids. For a number of cepheids no consistency can be obtained for the unreddened colour in all three two-colour diagrams. Pel considers that these discrepant cases are probably caused by the presence of photometric companions and concludes that at least 25 per cent of all cepheids are members of binary systems. The (B-L), (L-U) diagram is particularly sensitive to differences in line blanketing and Pel shows that there is a remarkably small range in heavy element abundance for short period population I cepheids, whereas a low metal content population II cepheid is clearly separated on this diagram. Fitting the five-colour data to model atmosphere spectra, temperatures, gravities, bolometric light curves, radius variations and the equilibrium values of these quantities are derived from the intrinsic colours of 98 cepheids with $P < 11$ days. The observational systematics of population I cepheids are studied in the instability strip. In the HR diagram an excellent fit of the data to the theoretical fundamental blue edge is obtained for $Y = 0.28$ and $Z = 0.02$. The present cepheid temperatures are significantly cooler than most of the cepheid temperature scales currently in use. As a result the pulsation and evolutionary masses are now in better agreement and the remaining mass discrepancy is not significant relative to the errors in observation and theory.

The problem of determining the intrinsic colours of individual cepheids continues to be of key importance in cepheid research. Dean et al. (MN 183, 569) demonstrate the usefulness of the BVI photometric system in determining the reddenings of galactic cepheids. The reddening free locus in the (B-V), (V-I) colours is constructed for cepheids by piecing together the loci for individual cepheids and then fixing the zero point from stars in clusters and associations whose reddenings are known independently. This locus, used in conjunction with reddening lines is employed to obtain colour excesses for about 60 cepheids. Extensive BVI photoelectric photometry has been obtained for galactic and extragalactic cepheids (Dean MNASSA 36, 3; Dean et al. Mem RAS 83, 69; Martin and Warren, unpublished). Comparison of colour excesses obtained with different photometric systems shows in general reasonable agreement although there are systematic differences with earlier work and, in particular, a strong systematic effect with spectroscopic reddenings. Photometry of neighbouring field stars has been used by Feltz and McNamara (PASP 88, 699) to determine the colour excesses of eleven galactic cepheids. A subgroup of cepheids with small and well-established reddening values is recommended to serve as standards for the calibration of reddening-free indices with intrinsic colour indices. Nikolov and Ivanov (Per. Zv. 20, 63) have compiled a new list of colour excesses of 161 cepheids based on previously published work. Canavaggia et al. (AA 43, 275) suggest that, in establishing an effective temperature scale for long-period cepheids, the discrepancies encountered by Schmidt can be resolved by deriving colour excesses from six-colour photometry. Schmidt (ApJ 203, 466) has investigated the colours of cepheids and yellow supergiants in open clusters. He finds that colour-colour relations for cepheids differ significantly from star to star and additionally that the non-variables may obey a different colour-colour relation from the cepheids. Szabados (Mitt. Sternw. Budapest - Szabadsaghegy No. 70) has presented new UBV photoelectric observations on 38 northern cepheids of period less than 5 days. Extensive UBVRI photometry for galactic and extragalactic cepheids has been published and discussed by Eggen (ApJ Sup 34, 1; ApJ Sup 34, 33). Ivanov and Nikolov (Proc. of Third European Astr. Meeting, p405) using previously published photometry have considered classical cepheids and their spatial distribution in our Galaxy.

C. Cepheids in open clusters and associations

Strenuous efforts have been made to increase the number of cepheids known in open clusters and associations in order to improve the calibration (especially the zero-point) of the PLC relationship for galactic cepheids. The available data on cepheids in clusters and associations has been summarised by van den Bergh (IAU Coll 37). One may identify a subset of "classical" calibrators which consists of the seven cepheids in clusters which are common to the lists of van den Bergh and of Sandage and Tammann. In attempting to define the zero point of the PLC relationship (with other coefficients adopted from the relationship for LMC cepheids) it is revealing that the "classical" calibrators show a very much smaller scatter than that obtained by inclusion of all calibrating cepheids (Martin, Warren and Feast, preprint).

Harris and van den Bergh (ApJ 209, 130) have shown that the 5.9 day cepheid CS Vel is a probable member of the cluster Ruprecht 79. Van den Bergh and Harris (ApJ 208, 765) have presented new UBV photometry for the highly reddened cluster Lynga 6 and the 10.8 day cepheid TW Nor. The reality of the cluster and the membership of the cepheid is supported also by Walraven photometry (Thé, AA 60, 423). Van den Bergh et al. (ApJ 208, 770) have shown that the cepheid SV Cru is not a member of the sparse cluster Ruprecht 97. From photometric and spectroscopic data, Turner (AJ 82, 163) has concluded that the 18.9 day cepheid VY Car is a probable member of the association Car OB1. Eggen (ApJ Sup 34, 1) has concluded that the stellar associations, of which the cepheids RS Pup and 1 Car have previously been thought to be members, do not exist. Despite its very different reddening, Warren (MN 178, 21P) has shown that the cepheid GU Nor is at the same distance as the galactic cluster NGC 6067. The membership of V367 Sct to the cluster NGC 6649 has been questioned by Flower (ApJ 224, 948). Eichendorf and Reipurth (IBVS 1450) have noted that the variable star HR 4511 is a possible very long period, low amplitude classical cepheid in the cluster Stock 14.

D. Extragalactic cepheids and the PLC relationship

A major BV photographic study of cepheids has been completed by Butler for 72 variables in the SMC (AA Sup 24, 299) and 98 variables in the LMC (AA Sup 32, 83). For cepheids in common with other observers comparison of the photometry shows good agreement with photoelectric data but systematic trends are revealed with previous photographic surveys. Martin, Warren and Feast (preprint) have completed an analysis of photoelectric BVI observations of 78 LMC cepheids. Again a comparison of the photoelectric observations of cepheids in common between different observers shows encouragingly small residuals. Both these studies have stressed the importance of selection effects in accounting for differences between observers in the coefficients obtained in the PL and PLC relationships. It is apparent now that in order to compare the properties of cepheids between one galactic system and another, and even to derive relationships within one system, a large statistically unbiassed sample of stars is required.

Previous arguments for the inclusion of a C-term in the PL relationship have rested primarily on theoretical grounds. Indeed, because of the difficulty in determining the value this coefficient observationally, the canonical value of the C-coefficient has been adopted as 2.52 on semi-theoretical, semi-empirical arguments. Butler and Martin et al.'s work shows that observationally the existence of a C-term considerably reduces the scatter in the PL relationship, thus enabling one to derive a more accurate distance modulus. The value of the C-coefficient however turns out to be close to the value expected if differential reddening from cepheid to cepheid were the primary effect. It is thus important to establish whether the observational value of the C-coefficient is determined by differential reddening (Clube and Dawe, preprint) or is an intrinsic property of the cepheids. The BVI photometry of Martin et al. establishes conclusively that the C-term in the LMC is caused primarily by intrinsic differences between cepheids and is not a consequence of differential reddening. However, Madore (RO Bull 182, 151) has found significant differential reddenings for cepheids in the LMC and the SMC from UBV photometry. He has also recalibrated the PL relationship by substituting the reddening free parameter W = V - 3.1 (B-V) for the visual luminosity. Madore (MN 177, 215) has derived colour excesses for 36 long-period cepheids in the Magellanic Clouds from UBV photometry. Excellent agreement is found between the photometric reddenings and independently calibrated spectroscopic reddenings, thus indicating that no gross intrinsic colour differences exist between long-period ($P \gtrsim 20$ days) cepheids in the Galaxy and the Magellanic Clouds. Eggen (ApJ Sup 34, 33) has obtained UBVRI observations of 21 cepheids in the LMC and SMC with periods greater than 35 days. He concludes (ApJ Sup 34, 1) that the LMC and galactic cepheids are very similar but that the long-period SMC cepheids are hotter on average at a given period. Van Genderen (AA 54, 737) has intercompared Walraven five-colour observations of 25 cepheids in the SMC with galactic cepheids. When corrected for absorption the position of the cepheids in the two-colour diagram shows that the SMC cepheids are bluer in comparison to their galactic counterparts.

On the question of amplitude as a third parameter in the PL relationship, Butler (RO Bull 182, 159) has found that for cepheids in the period range $0.4 < \log P < 0.9$ the data for the SMC tend to support Sandage and Tammann's conclusion (ie. the largest amplitudes occur at the blue side of the strip) whereas the data for the LMC show no clearly defined trend. On the other hand Madore (RO Bull 182, 151) has presented evidence, for cepheids in the LMC, SMC and the Galaxy, that the largest amplitudes occur at the red side of the strip. Also Yakimova (Soobsch. Gos. Astron. Inst. Shternberga, 177, 19) has analysed van Genderen's photometry of SMC cepheids and finds largest amplitudes at the red side of the strip. The clearest statement on the question of amplitude as a third parameter comes from Pel's work (Pel and Lub, IAU Symp 80, 229) where, at least for galactic cepheids, it is apparent that amplitude is not a good parameter to measure the position of a cepheid inside the instability strip as it varies too little with temperature, and for the low amplitude

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variables we cannot distinguish the red-edge cepheids from the blue--edge first overtone pulsators by amplitude alone.

Eichendorf and Reinhardt (AA 61, 827) have derived a statistically sound method to construct an envelope to a point diagram. This procedure has been applied to the period-amplitude diagrams of cepheids in the Galaxy and M31 with the conclusion that the upper envelopes are not significantly different. Van Genderen (AA 65, 147) has investigated the envelope line in the period-amplitude diagram for population I cepheids. He finds that the envelope line of the SMC and LMC differ significantly from each other and that the LMC line is intermediate between that of the SMC and the Galaxy) M31. A correlation between this progression and the average metal abundance in a stellar system is indicated.

Becker et al. (ApJ 218, 633) have constructed frequency-period distributions of cepheids in seven galaxies in the Local Group. These distributions have been compared with theoretical predictions. It is shown that evolutionary tracks of stellar models of intermediate mass are highly sensitive to changes in chemical composition. As either Z or Y is increased the entire frequency-period distribution is displaced to larger values of the period.

Cogan (AA 49, 17) has derived the moss-luminosity relationship of cepheids in the SMC and finds observational evidence for a change in slope at $M \sim 10\ M_{\odot}$ in agreement with theoretical predictions.

E. Mass (or radius) anomalies for population I cepheids

Considerable progress has been made on the resolution of the cepheid mass anomalies although further work requires to be done before some of the resolutions can be regarded as definitive. As pointed out by A.N. Cox (preprint and Proc., Conf. on Stellar Pulsation Instabilities) and J.P. Cox (Proc., Conf. on Stellar Pulsation Instabilities) there are six indirect methods of deriving the mass of a cepheid, which we shall call M_{evol}, M_{theor}, M_{puls}, M_{Wess}, M_{bump}, M_{beat}. In general M_{theor} agrees with M_{evol} but the other masses do not and they have been listed roughly in order of increasing discrepancy, culminating in M_{beat} which is typically a factor of 2 to 3 lower than M_{evol}. The problem is to obtain agreement between these different mass determinations.

Cogan (ApJ 221, 635) has preferred to express these anomalies in terms of radius. He has assembled radius and temperature determinations of classical cepheids from the literature and compares these with the theoretical relationships. Different methods of radius determination give significantly different results. In the log R, log P diagram it is pointed out that it is very difficult, for the double--mode and bump cepheids, to avoid a slope of unity which strongly conflicts with other evidence on population I cepheids. These radius discrepancies are similar to the mass discrepancies because any mass discrepancy can be translated into a radius discrepancy (of a factor 3 lower) by means of the PRM relationship.

The mass discrepancies have been discussed by many authors (Schmidt, ApJ 203, 466; Cogan, ApJ 211, 890; Cox et al., ApJ 212, 451, 214, L127, 220, 996, 224, 607; Takeuti, Sci. Rep. Tohoku Univ. 59, 67; Petersen, AA 62, 205; Pel and Lub, IAU Symp 80, 229; Faulkner, Proc. astron. Soc. Australia 3, 124). The new distance scale for the Hyades and the cooler effective temperatures obtained by Pel have largely removed the discrepancy between M_{puls} and M_{evol}, and the remaining difference is not considered significant. A.N. Cox (preprint) has discussed M_{wess}, derived from Wesselink radii, and concludes that, despite showing a large scatter, M_{wess} is systematically low compared to M_{evol}. However, considering the uncertainties and possible systematic errors in the Wesselink techniques, this discrepancy does not appear very significant.

The two remaining mass discrepancies, which appear to be really significant, are M_{bump} and M_{beat}. Discussion on the M_{beat} mass anomaly will be deferred to the section on double-mode cepheids, but we would note at this point that the only theory so far which can account for both the M_{bump} and M_{beat} anomalies is that of A.N. Cox and his collaborators. This theory involves a major alteration to the envelope structure by requiring a helium rich zone to produce a chemically inhomogeneous envelope. However, one theory which can explain the M_{bump} anomaly without recourse to a chemically inhomogeneous envelope is that developed by Carson and Stothers (ApJ 204, 461). The new Carson opacities considerably alter the structure of the envelope and detailed non-linear pulsation calculations (Vemury and Stothers, BAAS 9, 360 and preprint) have shown that the phase of the bump is changed in such a way that the mass anomaly virtually disappears. It will be very interesting to see precisely what effect these opacities have on the masses of double-mode cepheids.

F. Double-mode cepheids

Double-mode (or beat) cepheids have attracted considerable attention in recent cepheid research mainly because the mass anomaly exhibited by these stars is the greatest of all the mass anomalies (assuming that they are normal population I cepheids). The existence of the double periodicity means that these stars form a particularly sensitive probe of the structure of the stellar envelope and the theory of pulsation. The properties and importance of eleven, confirmed double-mode cepheids have been reviewed by Stobie (MN 180, 631). In the range 2-4 days these stars form a considerable fraction of the total number of cepheids of all population types. Their spatial distribution and radial velocity dispersion is similar to that of population I cepheids as is their chemical composition (Pel and Lub, IAU Symp 80, 229). Their position in the HR diagram shows no concentration to the red side of the strip but, if anything, they are associated more with the transition between fundamental and first overtone pulsation (Pel and Lub; Cogan ApJ 221, 635).

Faulkner (ApJ 216, 49; ApJ 218, 209; Proc. astron. Soc. Australia 3, 124) has established by Fourier techniques that strong mode interaction (equal in energy to the energy contained in the fundamental mode) is present in the double-mode cepheids TU Cas and U TrA (see also Kozar, IAU Coll 29, 183). A significant third period of low amplitude has been discovered in TU Cas, although the reality of this third period has been disputed by Cox et al. (ApJ 224, 607) and Hodson, Stellingwerf and Cox (preprint).

If double-mode cepheids are mode switching then observable effects should already be detectable since, according to Stellingwerf, the e-folding timescale of the mode switch is about 80 years. We should note at this point that, if only a single mode switch occurs in the evolution of a star across the instability strip, this timescale is quite inconsistent with the observed number of double-mode cepheids.

Shobbrook and Faulkner (preprint) have detected an amplitude change in U TrA over a timebase of 20 years where, although the total energy of the pulsation has remained constant, the first overtone energy has grown at the expense of the fundamental. Hodson et al. have examined the observations of TU Cas spanning 67 years but were unable to conclude whether or not the variation in amplitude found was real. However, Gieseking and Radeke (AAp Sup 33, 207) indicate that new observations of TU Cas do not agree with Faulkner's Fourier fit and they suspect a change in the mode interaction. Illês and Szabados (IAU Coll 29, 165) are continuing to obtain photoelectric observations of TU Cas. Madore et al. (MN 183, 13) found no evidence for a change in amplitude in the case of V367 Sct over a period of 50 years.

The mode identification of double-mode cepheids has generally been adopted as the fundamental and first overtone modes of radial pulsation. However Takeuti (IAU Coll 29, 171), on the basis of the excitation of different modes, considers that the question of pulsation mode is still open. Petersen (preprint) has examined the period ratios of the fundamental and first three overtones of radial pulsation and concludes that alternative mode identifications do not solve the problem.

One crucial member of the double-mode cepheid class is V367 Sct which is a probable member of the open cluster NGC 6649 (Efremov and Kholopov, Per. Zv. 20, 133; Kobayashi et al., Sci. Rep. Tohoku Univ., 59, 67; Madore et al. MN, 183, 13). However, Flower (ApJ 224, 948) has cast doubts on the cluster membership of V367 Sct and indicates that either the cluster or the cepheid is anomalous in some way. It is important to establish beyond all doubt whether or not this cepheid is a cluster member.

A remarkable spectroscopic effect has been found by Barrell (preprint) in that the frequency and strength of Hα emission in double-mode cepheids far exceeds that observed in single-mode cepheids of similar period. The strength of the emission appears to be correlated with the phase of the observation.

The evolutionary status of double-mode cepheids is a vital question. As Stobie (MN 180, 631) has pointed out their existence requires a substantial modification to our current understanding of pulsation theory and/or stellar evolution theory. Although it has been considered that the masses and radii of these stars are correct and hence that they occur in some unexplained evolutionary stage (Petersen, AA 62, 205; Cox et al. ApJ 212, 451; King et al. ApJ 195, 467) the present weight of evidence is heavily in favour of these stars being normal population I cepheids which happen to be pulsating simultaneously in two modes (Efremov and Kholopov, Per. Zv. 20, 133; Faulkner, Proc. astr. Soc., Australia, 3, 124; J.P. Cox, Proc., Conf. on Current Problems in Stellar Pulsation Instabilities; Pel and Lub, IAU Symp 80, 229). The problem then is to explain why the double-mode cepheids have such low masses and radii compared to population I cepheids of similar period.

To this end considerable effort has been expended on determining the sensitivity of these masses and radii to various assumptions. Petersen (AA 62, 205) has investigated the effect of varying theoretical input parameters on the periods of stellar envelope models and concludes that the masses and radii are accurate to 9 and 4 per cent respectively. Cogan (ApJ 211, 890) and Saio et al. (Sci. Rep. Tohoku Univ. 51, 144) have found that the period ratio of first overtone to fundamental modes of pulsation can be substantially reduced by deep envelope convection and greater values of the mixing length parameter.

It is difficult, however, to see how this can explain the M_{beat} discrepancy as double-mode cepheids are not concentrated to the red side of the instability strip. Cox et al. (ApJ 214, L127) have shown that the inclusion of rotation cannot change the period ratio sufficiently to resolve the mass discrepancy. Faulkner (ApJ 218, 209) has suggested that, because of the observed high degree of mode interaction in double-mode cepheids, period changes may occur due to the non--linear mode interaction. However, non-linear effects on the theoretical periods of a double-mode cepheid have been investigated by Cox et al. (ApJ 220, 996). They conclude that the first overtone to fundamental period ratio agrees with the linear theory value independent of the stage of mode-switching and hence independent of the non-linear coupling.

The only theory which has been able to account successfully (see, however, Cogan ApJ 225, L39) for both the M_{beat} and M_{bump} discrepancies is that due to Cox et al. (ApJ 214, L127; ApJ 222, 621). This theory requires the structure of the stellar envelope to be altered in a major way so that the periods and period ratios are changed in the right direction. The envelope structure required is that produced by a chemically inhomogeneous envelope with the inclusion of a helium rich layer ($Y = 0.75$) throughout the hydrogen and helium convection zones ($T < 70{,}000^{\circ}K$). The physical cause of this helium enrichment cannot be diffusion from below. Instead it is considered that a helium deficient stellar wind can maintain this chemical inhomogeneity.

G. Anomalous cepheids in dwarf elliptical galaxies

The anomalous cepheids are a group of cepheids typically in the period range 1 to 3 days which do not obey the PL relationship of cepheids in globular clusters being systematically overluminous for a given period. Such variables occur in dwarf elliptical galaxies, in the SMC (Landi-Dessy variables) and there is one case known in a galactic globular cluster, NGC 5466 (Zinn and Dahn ApJ 81, 527). Hodge and Wright (AJ 83, 228) have presented results on 23 variables in the Leo I dwarf galaxy and in particular show that 12 of these variables are anomalous cepheids. These variables have been discussed by Norris and Zinn (ApJ 202, 335) and Demarque and Hirshfeld (ApJ 202, 346) who both independently reached the same conclusion that these variables are young, extremely metal-deficient ($Z \lesssim 10^{-4}$) objects of mass approximately 2 $M_{\odot}$. Zinn and Searle (ApJ 209, 734) have obtained spectrophotometric scans of some of these variables and deduce that, provided these variables are pulsating in the fundamental mode, they must be 3 times as massive as RR Lyrae variables. Deupree and Hodson (ApJ 218, 654) have investigated the dependence on mass and chemical composition of the location of the instability strip and also conclude that the anomalous cepheids are more massive than the RR Lyrae variables. The existence of such stars may require us to revise drastically our precepts on star formation in dwarf elliptical galaxies as, if these stars are single systems, their mass implies that they are 10^9 years old. Norris and Zinn indeed conclude that star formation has been occurring over the last 1-8 x 10^9 years in dwarf elliptical galaxies. On the other hand Renzini et al. (AA 56, 369) have considered the possibility that the anomalous cepheids occur in binary systems where mass transfer has taken place, in which case their age could be 10^{10} years.

H. Miscellaneous

The Baade-Wesselink technique continues to be an important, independent method of calculating the radius of a pulsating star. The effects of observational error on the solution has been examined empirically by Evans (ApJ 209, 135).Evans (ApJ Sup 32, 399) has obtained new photometric and spectroscopic observations of cepheids in order to match accurately in phase the light and radial velocity curves. Wesselink radii are derived for 14 classical cepheids and the data used to intercompare period-radius relationships. Scarfe (ApJ 209, 141) has redetermined the Wesselink radius of Zeta Geminorum. Balona (MN 178, 231) describes how the principle of maximum likelihood may be applied to determine the radius of a pulsating star given the light, colour and radial velocity observations. This statistical method represents an improvement over the normal Baade-Wesselink approach and has been applied to 54 well-observed cepheids giving radius errors of no more than 10 per cent. Budding (Ap Sp Sc 48, 249) has applied optimal curve fitting procedures, based on the Baade-Wesselink methodology, to radial velocity data and six-colour photometry of the classical cepheids δ Cep and η Aql to obtain improved absolute magnitudes. Opolski (IAU Coll. 29, 175) has derived a radius for the double-mode cepheid TU Cas consistent with the low values predicted from period ratios.

A new method (angular diameter method) has been developed to derive the distance of a variable star (Barnes and Evans MN 174, 489); Barnes et al., MN 174, 503; MN 178, 661). The validity of this method requires that a variable star during its pulsation cycle should follow the surface brightness - colour relationship determined by non-variable stars and evidence has been presented to support this for the V-R colour (Barnes and Evans, MN 174, 489). The method requires V, R colour observations and a radial velocity curve and is considered capable of yielding distances accurate to 15 per cent. Fernie (MN 180, 339) has extended the method of Barnes et al. by obviating the need for a radial velocity curve. His method uses the observed close relationship between the total radial displacement and the product of the period and light amplitude. The radial displacement amplitude is equated to the angular amplitude derived by the surface brightness method in order to derive the distance to the cepheid. Evans (MN 181, 85P) has compared phase shifts observed between light and radial velocity curves with phase shifts determined by the angular diameter method of distance determination and generally finds good agreement.

Ultraviolet observations from OAO-2 have been obtained for eight cepheids (Hutchinson et al. AJ80, 1044; Hutchinson, Cepheid Modeling, p5; Hill, Cepheid Modeling, p31). For some of the cepheids the ultraviolet observations show excellent agreement with ground--based photometry in the wavelength region of overlap and are consistent with a simple extrapolation of the light curve properties from the visible region. This is not the case with β Doradus which in the ultraviolet shows two extra flux bumps in addition to the well known bump near maximum light. A model is constructed in which all three bumps are associated with the arrival of multiple shock waves at the stellar photosphere.

Photometric evidence for companions has been obtained by studying the colour-colour curves of cepheids (Janot-Pacheco, AA Sup 25, 169; Madore, RO Bull 182, 151 and MN 178, 505; Pel, AA 62, 75). The evidence is consistent in pointing to the fact that at least 25 per cent of cepheids have photometric companions (most of which are presumably in a binary system with the cepheids).

The question of distinguishing different pulsation modes in cepheids has never been as clear cut as in the case of the RR Lyrae variables. However, evidence is mounting that cepheids with low amplitude, sinusoidal shaped light curves and occurring at the blue side of the instability strip are probable first overtone pulsators (Gieren, AA 47, 211; Ivanov and Nikolov, ApL 17, 115; Connolly, BAAS 9, 360). The strongest evidence on this point for galactic cepheids has been presented by Pel and Lub (IAU Symp 80, 229) where, in a diagram plotting fractional radius amplitude versus distance in effective temperature from the fundamental blue edge, a group of low amplitude, blue pulsators is clearly distinguished from the remainder of the pulsators, very reminiscent of the difference between RR Lyrae type-c and type-ab variables.

Henriksson (AA 54, 309) has searched for low amplitude variability in the cepheid instability strip. Out of 121 stars selected from the Bright Star Catalogue to lie statistically in the cepheid instability strip, 15 stars have shown detectable light variations.

Period changes in cepheids have been studied by Hoffleit (IBVS 1131), Szabados (Mitt. Sternw. Budapest-Szabadsaghegy, No 70) and Petit (IBVS 1402). Hoffleit has shown that a remarkably strong correlation exists between the absolute value of the fractional period change and the period for variable stars in the instability strip. RR Lyraes, cepheids of both populations, semi-regulars and Miras all appear to fall on the same relationship. Petit has verified this in detail for cepheids of all types. Szabados has presented evidence showing that the period changes are abrupt in the overwhelming majority of cases and has noted examples where secular change in the light curve have occurred.

Broglia et al. (AAp Sup 33, 339) has studied the photometric behaviour of the exceptional population II variable, RU Cam, over a period of 10 years. After its abrupt change in light curve characteristics in 1964, RU Cam subsequently appears to have maintained a low amplitude, quasi-sinusoidal variation.

Spectrophotometric determination of the radii and effective temperatures of cepheids has been carried out by Fracassini et al. (IAU Coll 29, 127) and Rautela and Joshi (Ap Sp Sc 40, 455).

5. BETA CANIS MAJORIS STARS (J. Rountree Lesh)

The renewed interest in the β Canis Majoris problem that began in the late 1960's has continued through the period since the last General Assembly. New techniques, such as observations from spacecraft, polarization measurements, and high time-resolution spectroscropy, have been applied to these stars. A number of new variables have been found, and previously known variables have been more extensively studied. Both theoretical and observational work has been directed to finding the answers to such questions as the evolutionary state of the β Canis Majoris stars, their mode of pulsation, and their instability mechanism. No general agreement has been reached on any of these subjects, however, and much work remains to be done.

A. Reviews and General Studies

A review paper on the observational aspects of the β Canis Majoris stars was published by Lesh and Aizenman (ARAA 16, 215). Theoretical problems were reviewed by J.P. Cox at the Los Alamos Solar and Stellar Pulsation Conference, and by Osaki at IAU Colloquium No. 46. Aizenman and Lesh reviewed the problem of mode identification in β CMa stars at the Goddard-Los Alamos Conference on Stellar Pulsation Instabilities.

Shobbrook (MN 184 43; 185, 825; IAU Coll. 46) approached the problem of the evolutionary state of the β CMa variables by obtaining new, accurate β photometry for the bright stars in the region of the "instability strip". He concluded that the strip is so narrow that it is not resolved by the data, but that about 3/4 of the stars in the strip, to a distance modulus of 8.0, are variable. Shobbrook inferred that the variables must be very near the end of core hydrogen burning. On the other hand, Sareyan (Thesis, Univ. of Nice) argued that β CMa stars are found in a much larger region of the HR diagram than had previously been supposed, and that they cannot all be represented by a single evolutionary state. In another general study, Ferrari d'Occhieppo (IBVS 1243) found that there are at least 25 β CMa stars per 10^8 cubic parsecs, so that these variables are almost as frequent as, for example, Mira variables.

Meanwhile, M.A. Smith and his coworkers (Smith and Karp, Solar and Stellar Pulsation Conference; Smith, ApJ 215, 574, Conference on Stellar Pulsation Instabilities, and 4th Trieste Colloquium on Astrophysics; Smith and McCall, ApJ 223, 221) found short-timescale profile variations in a number of early B stars, some of which were β CMa variables and some of which were constant in light. They deduced that the profile variations were due to complex nonradial oscialla-tions, and hypothesized that the β CMa stars are a subset of a larger class of "line-profile variable B stars."

B. Searches for New Variables

Major survey problems in the southern hemisphere have been undertaken by Balona (Mem RAS 84, 101) and Jerzykiewicz and Sterken (Act Ast 27, 365; ESO Mess. 11, 5; IAU Coll. 46), in an effort to find new β CMa variables and to improve our knowledge of the statistics of these stars. Balona found 8 β CMa candidates, including 4 in the galactic cluster NGC 3293. Jerzykiewicz and Sterken observed 14-24 variable stars in the summer sky, but concluded that at most 4 of them were β CMa stars. Percy and his coworkers (Percy and Lane, AJ 82, 353; Jakate, AJ 83, 1179) surveyed samples of stars in both heispheres. While they did not report any β CMa candidates in the field, Jakate observed 3 candidates in the cluster NGC 4755. Meanwhile, 2 β CMa candidates were discovered in serendipitous fashion by Haug (ESO Mess. 9, 14) and Lesh and Wesselius (AA, in press).

C. Observations from Spacecraft

Spacecraft have been used with increasing frequency in the last few years to make photometric and spectroscopic observations of β CMa stars in the ultraviolet. Photometric investigations have been made with the OAO-2 (Lesh, ApJ 208, 135; 219, 947), TD-1A (Burger, Thesis, Free Univ. Brussels); Beeckmans and Burger, AA 61, 815) and ANS (Lesh and Wesselius) satellites. These studies have generally shown that the ultraviolet light curves are nearly in phase with the visual light curves, and that the amplitude of the variation increases with decreasing wavelength. The ultraviolet and visual light ranges can be used to deduce temperature changes and radii for some of these stars.

The spectrometers on board the Copernicus satellite were used

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by Hutchings and Hill (ApJ 213, 11) and by Lesh and Karp (IAU Coll. 42, 4th Trieste Colloquium on Astrophysics) to study variations in the line profiles of several β CMa stars. Hutchings and Hill confirmed the equivalent-width variation in the C IV lines of β Cep, while Lesh and Karp found a consistently blueward asymmetry in the Si III profiles of ν Eri and σ Sco. They attributed this to the superposition of a stellar wind on radial or nonradial pulsation. They also observed multiple components in the profiles of 12 and 16 Lac.

D. Polarization Measurements

Polarization measurements have been made for the first time on a number of β CMa stars. Rudy and Kemp (MN 183, 595), observed the circular polarization on the wings of the Balmer lines in 9 variables, in a search for the presence of magnetic fields. They obtained positive results on β Cep and probably on γ Peg, and suggested that fields as large as 1 kG may be typical of this class of stars as a whole. Odell (BAAS 10, 401) suggested that nonradial pulsation in β CMa stars should produce a net polarization, which would fluctuate with the pulsation period. Schafgans and Tinbergen (AA, in press) searched for such a time-dependent polarization in β Cep, with negative results.

E. Ground-Based Observations of Individual Stars

Traditional observing methods continue to be used on both well--known and recently discovered β CMa variables. Recent emphasis has been on spectroscropy at high resolution in time and wavelength. Here we briefly cite the observations star by star.

γ Peg: Spectrographic and photometric observations were used by Sareyan, Valtier, and Le Contel (AA 44, 215) to redetermine the period, which they found to be constant. A more detailed analysis (AA Sup 25, 129) by the same authors showed the existence of short--period light fluctuations, which were correlated with profile variations. Peters (ApJ Sup 30, 551) matched equivalent width data, profiles, and the continuous flux distribution for this star with an interpolated model atmosphere of T_{eff} = 21,500 K, log g = 3.7, and found no abnormalities. Smith and McCall (ApJ 221, 861) deduced from high spectral and time resolution observations that γ Peg is undergoing radial pulsation, with two separate rising and falling shells.

12 Lac: Heard et al (JRASC 70, 213) studied line width and asymmetry variations and radial velocity curves, and concluded that either radial or nonradial pulsation could explain the observed phenomena. They found the period to be decreasing by 0.34 s/century. Sato (ASS 48, 453) found a similar rate of decrease for the primary period, and studied the physical properties of the pulsation using Wesselink's method and the line profile variations. Allison et al (AJ 82, 283) showed that there is line doubling at certain phases in the pulsation cycle, and that the true radial velocity amplitude is therefore twice that obtained previously.

HR 6684: Bolton et al. (PASP 87, 595) found a blue light range of 0.033 mag and a radial velocity range of 18 km/s, while Pike (MN 184, 265) found 16.2 km/s for the velocity range. Rosenzweig (IBVS 1125) concluded that both the accepted period of 0.139889 d and its 1 c/d alias of 0.162723 d are possible periods for this star.

BW Vul: Cherewick and Young (PASP 87, 311) found no correlation of the Hβ index with phase. Goldberg et al. (AJ 81, 433) described the line profile variations in detail, and computed displacement and acceleration curves for the stellar atmosphere. Stamford and Watson (IAU Coll. 46) proposed a radial shock model for BW Vul. A current rate of period increase of 1.8 s/century was found by Valtier (AA 51, 465), as well as by several of the above authors. However, Goldberg et al. found that the secular period increase before 1955 was 3.7 s/century, and Tunca (IBVS 1386) assumed a discontinuous increase shortly after 1970-71.

Miscellaneous: Radial velocity measurements confirmed the membership of λ Sco and χ Sco in the class of β CMa variables (Lomb and Shobbrook, MN 173, 709), while β Cen was observed to show line profile changes with the same period as its radial velocity variations (Lomb, MN 172, 639). On the other hand, the β CMa variations in α Vir have almost died out (Lomb, MN, in press). Photoelectric observations were used to look for period changes in α Lup (van Hoof, MNASSA 34, 73), δ Cet (Tunca, IBVS 1259), and σ Sco (Sterken, AA 43, 321). Among the β CMa candidates observed were V986 Oph (Jerzykiewicz, Act Ast 25, 81), V600 Her (Hill et al., AA 51, 1), 53 Psc (Sareyan et al., AA, in press; Conference on Stellar Pulsation Instabilities), and 53 Ari (Lane, IBVS 1202).

F. Theory

Where β CMa stars are concerned, the primary problem of the theoretician remains the discovery of the instability mechanism. Different variations on the standard stellar models have recently been constructed and tested for stability. Special attention in recent years has been devoted to nonradial osciallations - their stability, and the observable properties that could be expected if they are present.

The possible effect of the adopted opacities on the stability of stellar models was investigated by Stothers (ApJ 210, 434) and Stellingwerf (AJ 83, 1184). Stothers computed theoretical models of 10.9 and 15 $M_\odot$ stars, using Carson's opacities. His ZAMS models had cooler effective temperatures than models based on earlier opacities, and intersected the β CMa instability strip only once, in the core-burning phase. But all the radial and nonradial modes tested ($0 \leq \ell \leq 5$) were stable. Stellingwerf studied the destabilizing effect of the He^+ ionization edge (which produces an opacity feature near $T = 1.5 \times 10^5$K) on 12 and 8 $M_\odot$ models. The models remained stable, but became unstable if the opacity "bump" was artificially enhanced. J.P. Cox (private communication) has pointed out that "envelope excitation mechanisms" like the above have the advantage of producing an "instability strip" with negative slope - i.e., parallel to the main sequence, as observed for β CMa stars.

Osaki and Shibahashi (PASJ 28, 105, 199, 533) continued to work on the stability of massive stellar models in the secondary contraction and hydrogen shell-burning phases. A 10 $M_\odot$ model was found to be stable against quadrupole ($l = 2$) oscillations in the contraction and shell-ignition stages, and trapped nonradial gravity modes were vibrationally stable in the early shell-burning stages of 5 and 11 $M_\odot$ models. For 20 and 40 $M_\odot$ models, some g-modes with $\ell \simeq 10$ were overstable in the early shell-burning stage, but this instability was short-lived. Similarly, some gravity modes trapped in the zone of increasing molecular weight were unstable to Kato's mechanism in stars of 15 and 30 $M_\odot$ with a semiconvective zone, but the value of ℓ was too high to explain β CMa-type oscillations.

Sreenivasan and Wilson (Conference on Stellar Pulsation Instabilities) also concluded that the β CMa phenomenon is unlikely to be connected with semiconvection, since mass loss from 15-30 $M_{\odot}$ stars would prevent them from exhibiting semiconvective zones, while these zones would be small in any case for 10-12 $M_{\odot}$ stars. Van der Borght (PASA 3 (1), 89), on the other hand, thought that the overstable oscillations produced by the onset of nuclear reactions in a hydrogen-burning shell might be responsible for the β CMa oscillations, since they result in a periodic variation of the luminosity.

Aizenman and Weigert (AA 56, 457) studied the nonradial quasi-adiabatic stability of some very unusual models for β CMa stars - pre-main-sequence models with complete mixing, and post-main-sequence models with mass loss. All the models turned out to be stable. Meanwhile, Aizenman et al. (AA 58, 41) found that rapid shifts of frequency (bumping or avoided crossings) of the linear, adiabatic, nonradial modes of oscillation occur in stars evolving away from the main sequence, and thought that these might be connected with the beat phenomenon in β CMa stars.

In the area of mode identification, Kubiak (Act Astr. 28, 153) calculated line profiles and radial velocity curves for nonradially oscillating stars with values of ℓ up to 4. He found that single--period variables with sinusoidal velocity curves could be identified with stationary (m = O) oscillations. Stamford and Watson (MN 180, 551; PASA 3 (1), 75; IAU Coll. 46) computed light, color, and radial velocity variations for radially and nonradially oscillating models. A comparison of the color variations with observations suggested the presence of both radial and nonradial oscillations with ℓ = 2. Dziembowski (Act Astr. 27, 204) showed that nonradial oscillations cannot be distinguished from radial ones on the basis of the amplitude ratio of the radial velocity and light variations. He suggested instead using a generalization of the Baade-Wesselink method.

6. DELTA SCUTI STARS/DWARF CEPHEIDS (M. Breger)

A. General

More than 200 of these short-period pulsators are now known. A new review paper is expected to be published in the February, 1979 issue of the PASP. Two new variability surveys have been published. McInally and Austin (MN, 184, 885) tested 29 field stars for variability and found 6 variables. They report an unusually high period of $0^{d}.361$ for one star (HD 185969), but more observations of this star would be useful. Slovak (Ap.J., 223, 192) found a relative incidence of variability of 25% in the Alpha Perseus cluster, in good agreement with that found by Breger in other clusters (IAU Symp. 67, 231). The rotational velocity of the variables in Alpha Perseus resembles that in the similar Pleiades cluster in that the main-sequence variables have a slightly lower average rotational velocity than the constant stars.

The inverse radial velocity curve lags the light curve in V by about 0.09 periods, according to Breger, Hutchins and Kuhi (Ap.J., 210, 163). They also find the velocity to visual light amplitude ratio to be 92 km $s^{-1}mag^{-1}$. Dziembowski (Acta Astr., 27, 203) shows from calculations of nonradial p modes that nonradial osciallations cannot be distinguished from radial pulsation on the basis of amplitude ratios of radial velocity and light variations. He suggests the use of the Baade-Wesselink Method instead.

Antonello, Arienti, Fracassini and Pasinetti (Astr. Ap., 66, 37)

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reported very large radial velocity and equivalent width changes in three early A stars, based on photographic work. However, Breger, Light and Scholtes (Astr. Ap., in press) repeated the observations of two stars with a photoelectric spectrum scanner and found no variations. A group at Allegheny Observatory (Beardsley et al., preprints) believes that several hot stars, including Vega, are short--period variables. Kurtz (IBVS, 1436) reports the variability of an Ap star inside the instability strip, HD 101065 (Przybylski's star) with an unusually short period of 12.1 minutes. Kurtz and Wegner (Ap.I., in press) raise the interesting speculation that the high magnetic field of 2200 gauss forces the star into a high nonradial pulsation modes.

Stellingwerf (Ap.J., in press) examines the pulsational drivin zones with linear stellar models. Apart from the usual He II and H ionization zones he finds an additional (third) driving zone caused by the coincidence of the maximum photon flux with the frequency of the He II ionization edge.

Valtier, Baglin and Auvergne (preprint) have examined the importance of the H ionization zone to drive pulsation. This is important since the pulsating δ Del stars may be deficient in He in the He II ionization zone due to the diffusion. Only a marginally positive result for the H ionization was found.

B. Periods

There exists considerable evidence that these short-period variables pulsate in radial as well as nonradial modes. However, relatively little agreement on the exact period structures seems to exist from observer to observer. The problems can generally be traced to insufficient data, and sometimes, to deficient methods of analysis. A good summary, which is only slightly dated, is given by Fitch (Proc. IAU Coll., 29, 167). Valtier and co-workers (Astr. Ap. Suppl., 15, 115 and 18, 235) report that no stable frequencies exist for HR 432, 515, 812, 8006 and 9039. Warman (preprint), however, disagrees and finds stable periods which fit Valtier's data as well as earlier observations. McAlary and Percy (PASP, 87, 789) report three radial periods for 4 CVn. Warman, Pena and Arellano-Ferro (AJ, in press) find a stable multiperiod structure for this star over the last 21 years. A series of preprints by Kurtz conclude generally complex (nonradial) pulsation modes. Wizinowich and Percy (PASP, in press) find a radial period ratio of 0.774 for 44 Tau. Groups at Uttar Pradesh (Sinvhal, Gupta, Joshi and Rautele) and Texas (Loumos) also report a large observational multiperiodicity programme.

The theoretical problem with the high P_1/P_0 ratio for the large--amplitude variables may be resolves. J. Otzen Petersen (Astr. Ap., preprint) shows that in the P_1/P_0 range occupied by the Delta Scuti stars, the period ratios are extremely sensitive to composition and cannot provide unique information on stellar masses. Most of the observed period ratios can, however, be fit with normal masses and compositions. Cox, King and Hodson (Ap.J., in press) as well as Stellingwerf (Ap.J., in press) reach very similar conclusions. The largest radial P_1/P_0 ratio known, viz. 0.778 for SX Phe, can be fit by a 1.1 solar mass star with Population II composition (in good agreement with observations). Simon (Ap.J., preprint) explains the observed period ratios through a different hypothesis involving a resonant interaction between two excited modes. He requires low masses.

C. Large-Amplitude Variables

Recent evidence suggests that amplitude of pulsation is not a good discriminator of evolutionary status, mass and composition. The subdivision between Delta Scuti stars and Dwarf Cepheids (=RRs=AI Vel=amplitudes larger than 0.3 mag) appears not to be justified. Metal-poor variables appear among both the low-amplitude and large - amplitude variables (as pointed out by Eggen and others). In a large number of papers, two groups of workers led by McNamara and Breger respectively, have analyzed individual large-amplitude variables. Good summaries of their work can be found in McNamara and Feltz (PASP, 90, 275) and Breger (Poc. Solar and Stellar Pulsation Conf., Los Alamos, 47). These papers show that most large-amplitudes variables share the evolutionary status, abundance and mass with the smaller-amplitude stars. Balona and Martin (MN, 184, 1) find a Wesselink radius of 2.9 solar radii for RS Gru and deduce a post-main sequence state of evolution. The Barnes-Evans method fails to give realistic radii for RS Gru, presumably due to the presence of a companion.

The large-amplitude variable, SX Phe, is no longer the only extremely metal-poor, high-velocity case known. In an important discovery, Berg and Duthie (Ap.J. Letters, 215, L25) found GD 428 to be variable. McNamara and Feltz (PASP, 90, 275) confirm the variability and the star's lack of metals. They also derive log g = 4.18.

D. Pulsation and Metallic-Line Characteristics

Since the original announcement on the constancy of classical Am stars, several investigations have been made to confirm or refute this hypothesis. One of the reported exceptions, 32 Vir, has been examined by Kurtz, Breger, Evans and Sandmann (Ap.J., 207, 181). They find that the Am star has a normal A-star companion which they believe is pulsating. Mitton (preprint), on the other hand, suggests that the primary metallic-line star does indeed pulsate but that it is not a classical Am star and should be classified as an evolved Am star (δ Del) instead. In a new variability survey, Stickland has confirmed the short-period constancy of classical Am stars (Observatory, 97, 11).

Pulsation seems to be excluded only for the classical Am stars. The δ Del stars (evolved Am) seem to have an affinity for pulsation. Kurtz (Ap. J. Suppl., 32, 651) finds the δ Del stars to be a spectroscopically inhomogeneous group. Many spectra are similar to those of evolved Am stars with fewer overabundances of rare earths. Two Marginal Am stars (Am:) stars were also found to be variable by Kurtz (preprint).

7. T TAURI STARS AND RELATED OBJECTS (G.F. Gahm)

New observational results and current ideas concerning the physical structure and evolution of nebular variables, like stars of the Orion population, have been discussed at the IAU Symposium No. 75 in Geneva, 1976; the IAU Colloquium No. 42 in Bamberg, 1977; the Colloquium on "Early stages of stellar evolution" in Kiev, 1975 (published by Naukova Dumka, Kiev, 1977) and the IAU Colloquium No. 52 in Tucson, 1978. The proceedings of these meetings, like the reviews by Strom et al. (Ann. Rev. Astron. Astrophys. 13, 187) and Cohen (Quart. J. Roy. Astron. Soc. 19, 177) cover a large body of recent work and the present report is intended only as a brief overview of certain observational data and some current problems.

The T Tauri stars and the nebular Ae and Be stars show emission lines in the optical spectral region. In general, the broad emission lines are seen superimposed on an absorption line spectrum which can be classified according to spectral type and luminosity class. In many objects the absorption line spectrum is more or less veiled by a blue excess continuum, which in extreme cases extends into the red spectral region. The spectral surveys by Rydgren et al. (Astrophys. J. Suppl. 30, 307) and Cohen and Kuhi (1978, in press) indicate that when the blue spectral region is totally veiled, the red spectral region usually indicates a spectral type of late K or M. This is a very important result since many of the strongly veiled stars previously were classified as types F or G. Earlier statements concerning the positioning of stars in the HR diagram and relations between various observed parameters (like A_v) and spectral type should thereby be modified. Some of these statements can be proven to be invalid.

A good criterion on luminosity of the stellar component of the late-type stars is probably the strength of the red CaH bands. These were used by Mould and Wallis (Mon. Not. Roy. Astron. Soc. 181, 625) to demonstrate that the stellar component fall above the main sequence in the subgiant region. It should always be remembered that the relation between spectral type/luminosity class and effective temperature/M_v does not necessarily follow a "normal" law.

Two special characteristics of the absorption line spectra can be pointed out. Firstly, the lines are generally broader than for field stars of the same MK class. This effect is usually attributed to larger than normal rotational velocities of the stars. If so, the positive relations found for stars in NGC 2264 by Cohen and Kuhi (IAU Symp. No. 75 p. 203) between v sin i on one hand and degree of Hα emission and luminosity on the other hand could provide us with most important information concerning loss of angular momentum of the stars with evolutionary phase. The question remains open, whether the rotational energy liberated by the spin down of the star is transported away in form of mass loss or whether a considerable fraction reappears as radiation energy from an emitting volume around the star. Secondly, the Li I doublet lines at λ 6707 are unusually strong. This property is now well established through the extensive spectral survey by Herbig (Astrophys. J. 214, 747). It seems now quite safe to state that the surface Li abundance of T Tauri stars simply reflects the abundance of the original proto cloud and that the strength of the Li lines is one of the most important indicators of youth of a star.

A considerable number of optical spectrograms of certain T Tauri stars has accumulated over the last 35 years or so. It appears, that even if there are statements in the literature about changes in the appearance of the absorption line spectrum with time, many stars are repeatedly found to be of the same spectral type. For instance, there are now some 100 spectrograms or spectral scans taken of DI Cephei (for references covering the last three years we quote Gahm et al., Variable Stars 20, 381; Cohen and Kuhi, in press and Mundt, in press). The spectral type of DI Cep stays close to KO. Therefore, there seems to be a strong indication for this and other stars that the light and colour variability is not caused primarily by dramatic changes in the effective temperature of the stellar component. Rather, we must seek the origin of the brightness variations in the emitting gas envelope and/or in circumstellar dust shells. Before entering a discussion on these non-stellar components we note that a most thorough spectral and polarimetric study of the Herbig Ae and Be stars has been undertaken by Garrison and Anderson (Astrophys. J. 218, 438; ibid. 221, 601) and Garrison (Astrophys. J. 224, 535) who found little if any intrinsic difference between the nebular and non-nebular emission line stars of these spectral types. We also note that in the case of stars belonging to the FU Orionis class, a most dramatic change in spectral appearance takes place. (Herbig: Astrophys. J. 217, 693; Elias: Astrophys. J. 223, 859).

The emitting gas envelope is manifested in the emission lines and the continuous excess emission that is seen in the ultraviolet, the blue (the blue veiling) and the infrared spectral regions. For the latter we can state that since there seems to be little doubt that hydrogen free-bound emission gives a large contribution to the UV excess emission it follows that at least part of the IR excess originates from gas emission. However, the IR excess can also be explained as emission from grains in a circumstellar dust envelope. Quite divergent opinions exist on which of these processes dominate. It may be that both effects are present with different relative importance on different stars (Rydgren et al.: Astrophys. J. Suppl. 30, 273; Kuan: Astrophys. J. 202, 425; Rydgren: Publ. Astron. Soc. Pacific 88, 111; Cohen and Schwartz: Mon. Not. Roy. Astron. Soc. 174, 137; Thompson and Reed: Astrophys. J. Lett. 205, L 159; Warner et al.: Astrophys. J. 213, 427; Simon and Dyck: Astron. J. 82, 725; Wenzel: Astron. Nachrichten 296, 183; Rydgren: Publ. Astron. Soc. Pacific 89, 823; Schwartz: Astron. J. 83 785; Wenzel and Brüchner: Mitt. Veränderliche Sterne 8, 35).

At radio continuum wavelengths only a few objects have been detected so far. For others upper limits have been set. (Altenhoff: Astron. Astrophys. 46, 11; Harris: Mon. Not. Roy. Astron. Soc. 174, 601; Brown et al.: Mon. Not. Roy. Astron. Soc. 175, 87P; Woodsworth and Hughes: Astron. Astrophys. 58, 105; Schwartz and Spencer: Mon. Not. Roy. Astron. Soc. 180, 297). Emission at mm and cm wavelengths clearly originates in circumstellar ionized gas envelopes.

The first broad band flux measurements of Orion population stars at wavelengths shortward of 3000 A were obtained by de Boer (Astron. Astrophys. 61, 605). More detailed spectra obtained with the IUE satellite and covering part or all of the spectral region $\lambda\lambda$ 1150--3200 A are now available for T Tau (Penston et al.: in preparation), RU Lup (Fredga et al.: in preparation), S Cr A (Appenzeller and Wolf: Astron. Astrophys., in press) and DI Cep (Gahm et al.: in preparation). The presence of emission lines from several times ionized elements like C IV and Si IV indicates that in addition to the low temperature shell component seen in the optical spectral region there are shell regions of very high temperature ($\sim$ 100 000 K) around the stars. These observations introduce new and interesting aspects relevant to the understanding of the nature of the objects.

One of the existing major theoretical problems is to explain why the stars are surrounded by such energetic and luminous emitting gas shells and to formulate models describing the physical structure of these shells. Quite different ideas on these matters are in circulation.

The discovery of inverse P Cygni profiles that occasionally are seen present in the higher Balmer lines of a number of objects has led to models that, at least for these stars, favour infall of surrounding interstellar material as the main source of energy for the emitting gas envelope. The profiles of the sometimes very broad emission lines are understood on the basis of the velocity field of the infalling gas (Ulrich: Astrophys. J. 210, 377; Appenzeller and Wolf: Astron. Astrophys. 54, 713; Bertout: Astron. Astrophys. 58, 153; Wolf et al.:

Astron. Astrophys. 58, 163; Bertout et al.: Astron. Astrophys. 61, 737; Appenzeller: Astron. Astrophys. 61, 21: Appenzeller et al.: Astron. Astrophys. 63, 289). As a main cause of the brightness variations of the stars the possibility of changes due to density fluctuations in the infalling material has been pointed out (Mundt: Astron. Astrophys.: in press). For the proto-type of these so-called YY Orionis stars, namely YY Ori itself, Walker (Astrophys. J. 224, 546) arrived at the conclusion that the brightness variations are mainly due to variable opacity in a circumstellar dust shell in the line-of--sight to the star.

Many of the references quoted above in connection to observations of energy distributions of Orion population stars also include discussions on different aspects of variations due to changes in circumstellar dust layers and/or in circumstellar ionized gas. Closely related to the question of variations in the ionized gas are the observations leading to statements about extremely rapid (on time--scales of minutes or hours) changes in the intensities or profiles of certain emission lines or in the ultraviolet continuum (Kolotilov and Zaitseva: Variable stars 20, 153; Kuan: Astrophys. J. 210, 129; Zaitseva and Luyty: Variable stars 20, 266; Mundt: in press). Undoubtedly variability in the properties of the ionized gas plays at least some role in the brightness variations. On the other hand, one can find objects which seem to vary exclusively because of changes in a circumstellar dust envelope. One exemple is HR 5999 discussed by Thê and Djie (Astron. Astrophys. 62, 439).

Ideas on magnetic fields extending from the surface of the stars and acting as a relay mechanism for transporting variable amounts of mechanical energy into the circumstellar ionized gas and lining up circumstellar dust grains to produce circumstellar polarisation has been developed by Petrov and Schcerbakov (Proc. 3rd European Meeting, Tbilisi p. 163) and Gehrsberg and Petrov (Sovj. Astron. Lett. 2, 449). This model seeks to explain the energy source of the emitting ionized gas, the cause of the changes in brightness as well as the mechanism behind the FU Orionis type phenomenon.

We know that the energetics of a star in formation is governed by the energy liberated from accretion of interstellar material and also that young stars eventually will develop surface phenomena of chromospheric nature, e.g. similar those on the sun. Consequently, the problem is to understand when and why the circumstellar gas emission switches over from one energy source to the other. And clearly, the solar chromosphere is not dependent on accretion of interstellar material for its existence.

A closely related question is how to derive bolometric luminosities for the stars. If the excess emission is due to infalling material, the energy flux liberated should not be included in the computation of the bolometric luminosities for comparisons with theoretical evolutionary tracks. If, on the other hand, the energy comes from a mechanical flux generated in the star, rotational braking or any other internal source, the excess emission should be included.

This review has concentrated on nebular variables with a distinct stellar component. During the last years a number of variable but non-stellar objects have been discussed as possible pre-main-sequence objects. These have not been discussed here.

We close this review by mentioning that a number of works have been directed towards a description of the molecular content in the circumstellar or interstellar surroundings of Orion population objects. The following molecules have been looked for with various success: OH Rudnitskii: Sovj. Astron. J. 53, 1225; Lang and Willson:

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Astrophys. J. Lett.: in press; Gahm et al.: Astron. Astrophys.: in press. CH_3OH Buxton et al.: Astron. J. 82, 985; H_2 Beckwith et al.: Astrophys. J. Lett.: 223, L 41. A search for fluorescent diatomic modecules was done by Gahm et al. (Astron. Astrophys. Suppl. 27, 277).

8. RR LYRAE VARIABLES (B. Szeidl)

Two important catalogues of RR Lyrae stars were published. The graphical catalogue (Cacciari and Renzini AA Sup. 25. 303) gives the period amplitude diagram, the period-frequency distribution and the period cumulative diagram for RR Lyraes in the globular clusters, in the solar neighbourhood and in some samples situated near the galactic centre, in the galactic halo and in the nearest extragalactic systems. The bibliographical catalogue, available on magnetic tape and on microfiches, gives bibliographical references for 5855 field RR Lyrae stars with 6607 entries (Heck, Lakaye AA Sup 30. 397).

Bookmeyer, Fitch, Lee, Wiśniewski and Johnson have finished their UBV photometry on about 180 field RR Lyrae stars. The second list (Revista Mexicana de Astron. y Astrof. vol. 2. No. 3. 235) contains observations of 70 stars. The two lists give mean colours and magnitudes at light extrema for 174 RR Lyraes adequately observed during the course of this program.

Dean, Cousins, Bywater and Warren published BVI photometry on 9 southern RR Lyraes (Mem. RAS 83. 69). Lub obtained light and colour curves in the Walraven VBLUW system for 90 field RR Lyrae and short period variables (AA Sup 29. 345). Using these observations he discussed the reddening and blanketing corrections and physical properties of RR Lyrae stars (ESO Sci. Prepr. 13).

Considerable work has been devoted to studying the metal content and other physical characteristics of RR Lyrae stars. From uvbyβ photometry of SW And (McNamara, Feltz PASP 89. 699) and SS Psc (McNamara, Redcorn PASP 89. 61) the metal abundance, effective temperature and gravity of these stars were derived. UBV photometry of RR Lyrae stars in ω Cen and M4 (Sturch, AA 46. 133; PASP 89. 349 and 90. 264) made possible to discuss the problems of metallicity and cluster reddening. The observed UV excess in ω Cen confirms the variations in [Fe/H] found from recent spectroscopy.

[Fe/H] values have been spectroscopically determined and analysed for a large number of field RR Lyrae stars (Butler, Carbon, Kraft BAAS 8. 347; ApJ 210. 120 and Rodgers ApJ 212. 117) and cluster variables (Butler ApJ 200. 68; Freeman, Rodgers ApJ 201. L71; Butler, Dickens, Epps ApJ 225. 148; Manduca, Bell ApJ 225. 908). Observations of RR Lyrae stars in ω Cen have revealed a diversity in the composition of these stars.

Kukarkin reviewed the various metallicity criteria and discussed them together with other features of globular clusters (IAU Symp. 67. 511). Frolov deduced a relation between the pulsating parameter $\Delta V/\Delta(B-V)$ and the metal abundances (A Cir USSR 941).

Bukhantsova and Nikolov investigated the group of galactic RR Lyrae variables with periods about $0^d.4$ (A Cir USSR 966). This group is well defined and might have special evolutionary aspects.

A system of criteria of two-dimensional quantitative spectral classification of RR Lyrae type variable stars were established by Fenina (Per Zv 20. 103). Using this method, absolute magnitudes of SW And, XZ Cyg and RZ Lyr could be determined (Fenina A Cir USSR 892).

Following a method advocated by van Hoof mean radii of some RR Lyrae variable stars were determined by Woolley and Davies (MN 179. 409). This method gives acceptable results and leads to mean absolute magnitude of $0^{m}.45$. The velocity ellipsoid of RR Lyrae stars has been computed and the best figures are roughly in the ratio $\bar{R}^2 : \bar{\Phi}^2 : \bar{\Theta}^2 =$ $= 3:2:1$ (Woolley MN 184. 311).

At the Sonneberg observatory extensive works were carried out on the variables discovered there. Gessner finished the processing of the 93 RR Lyrae variables discovered by Hoffmeister in the area η Arae (Veröff. Sternw. Sonneberg 8. 341). Meinunger derived the distances and the density distribution of RR Lyraes in the Sonneberg fields near the North Galactic pole (AN 298. 171).

During the past three years a great number of visual, photographic and photoelectric maxima have been collected for known and new RR Lyrae stars. These are mostly published in A. Cir. USSR, MVS, IB, Per Zv and Per Zv Sup. Accurate photoelectric observations indicate that HX Ara, originally classified as a W UMa star, is an RRc variable (Duerbeck, Walter IB 1224, AA 49. 471), while BC Dra, misclassified as δ Cep variable, is in reality an RRab star (Szabados, Stobie, Pickup IB 1197). Photoelectric observations and radial velocity measurements were published by Andrews (MN 172. 271) on the RRc variable HD 268892.

The study of period changes of RR Lyrae variables is still very popular. Szeidl gave a review of the observed phenomena of period changes (IAU Symp. 67. 545). He showed that both abrupt and smooth changes in period might occur. The dependence of the period changes on the evolutionary track through the instability strip has still found no explanation.

O-Cs were given for UY Cyg, SU Dra, CG Peg and AN Ser by Batyrev (Per Zv Sup. 2. 207), for TV Boo, TW Boo and RR Leo by Demjanovskij (Per Zv Sup. 2. 301), for AV Peg by Grigorev (Per Zv Sup. 2. 291) and for XX And, RS Boo, UY Boo, RZ Cep, RV CrB, XZ Dra, RW Dra, SV Eri, RR Gem, SZ Hya, Y LMi, RV UMa and SX UMa by Firmanyuk (IB 1152, A Cir USSR 924). He noticed that some of the O-Cs show possible periodicity in the period variations with a cycle length of 15000-40000 days. Olâh and Szeidl commenced an investigation of the period changes of field RR Lyrae stars. Their results on AT And, SU Dra, RR Leo, TT Lyn and AR Per have been published (Budapest Mitt. 71).

The Large and Small Magellanic Cluds have been searched for variable stars by Graham (PASP 89. 425 and 87. 461). Variables have been also found by Kinman, Sryker, Hesser (PASP 88. 393) in and around NGC 1841 and the extent of the Magellanic Clouds. A search for rapid variables and RR Lyrae stars in the LMC on ESO Schmidt plates is carried out by Geyer (IAU Symp. 67. 557).

Zinn and Searle investigated two RR Lyrae stars in the Draco system (ApJ 209. 734). The mean effective temperatures and the luminosities have been used to find their masses.

The sparsely populated globular cluster in Reticulum found by Sérsic has been investigated to V = 19.5 mag by Demers and Kunkel (ApJ 208. 932). Periods are given for 19 of 22 RR Lyrae variables found.

The investigation of multiple periodic RR Lyrae stars is still an outstanding problem.

Ultraviolet photometry of RR Lyrae was carried out from the Orbiting Astronomical Observatory-2. Hutchinson, Hill and Lillie (ApJ, 211. 207) used a hydrodinamical model to show the influence of atmospheric shock waves on the ultraviolet light curves. Their model indicates that visible light observations of the bump in the light

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curve before rising light and the stillstand in rising light are due to the energy deposition by two separate shock waves.

At the Konkoly Observatory, in Hungary RR Lyrae has been intensively observed and, its four-year cycle and the large phase shift in the 41-day period at the beginning of the new cycle was confirmed.

Szeidl (IAU Colloq. 29, Part I, 133) gave an observational review of RR Lyrae stars with Blazhko-effect. He discussed the problems of frequency and general characteristics of multiple periodic RR Lyrae stars. Kanyô (IAU Colloq. 29, Part II, 211) investigated the period-fluctuation of these stars and found out that the RR Lyrae stars of shorter secondary periods have more complex O-C structures than those of longer ones. Romanov (IAU Colloq. 29, Part II, 191) surveyed some characteristics of Blazhko-effect in RR Lyrae-type variables and discussed the hypothesis of the interference of radius oscillation first outlined by Tsessevich.

Fenina and Romanov's method of quantitative spectral classification of RR Lyrae-type variable stars (IAU Colloq. 29, Part II, 229) was applied to some variables with Blazhko-effect. The spectral pecularities of SW And was discussed (Fenina, Romanov, A Cir USSR 862) and a new period of $36^{d}.92$ of the Blazhko-effect in SW And was given (Lysova, Romanov and Firmanyuk, A Cir USSR 982). Romanov, Tsessevich, Shakun and Zgonyaiko (A Cir USSR 981) discovered some pecularities of light variation and anomalous Blazhko-effect in DR And. Recent observations (Lange and Firmanyuk, A Cir USSR 864) show the Blazhko-effect in ST Boo, too. A few papers (Fenina, A Cir USSR 862, Taylor, JAAVSO 4. 25, Blasberg, MVS 7. 31, Bezdenezhny Per Zv Sup 3. 125) have dealt with XZ Cyg. Photoelectric observations of this star were discussed by Kunchev (Per Zv 19. 477) and by Kunchev and Romanov (Per Zv 19. 471) Lebedev (Per Zv Sup 2. 313) observed XZ Dra photoelectrically but was unable to determine its secondary period. Romanov (Per Zv 20. 299) investigated the radial velocities in RZ Lyr and determined the radial velocity amplitudes at different phases of the secondary period. Romanov, Fenina and Klabukova (A Cir USSR 923) studied the variation of Δs and p indices of this star. AR Ser, which has anomalous Blazhko-effect, was thoroughly investigated at the Odessa Observatory (Firmanyuk, IB 1245; Tsessevich A Cir USSR 885, IAU Colloq. 29 Part I.3, Per Zv Sup. 3. 93). A detailed UBV photometry of the multiple periodic RR Lyrae star RV UMa was carried out by Kanyô (Budapest Mitt 69). Frolov called the attention to the interesting "ultraviolet" Blazhko-effect of X Ari (IB 1097). The multiple periodic RRc star TV Boo was observed by Firmanyuk (A Cir USSR 843).

Goranskij (Per Zv Sup. 2. 323) made an attempt at determining the secondary periods of RR Lyrae variables in globular clusters (No. 30 in M53 $P_s = 37^{d}.6$ and No. 2 in M5 $P_s = 132^{d}.4$).

AC And is unique in having three identifiable periods. Its fundamental and first and second overtone radial pulsation modes are all excited and nonlinearly coupled (Fitch and Szeidl, ApJ, 203. 616). This star provides a good opportunity for testing the pulsation theory and determining its mass (Cox, King and Hodson, IAU Colloq. 29 Part II. 233; BAAS 9. 360, ApJ 212. 451; Stellingwerf, IAU Colloq. 29. Part I. 153; Petersen, IAU Colloq. 29. Part I. 195, AA 65. 451). The U-B and B-V colours of this triple mode variable (Jakate ApJ 224. 603) are compatible with the idea that AC And is an RR Lyrae star.

AQ Leo has also complex light variation. The star is found to be an RR Lyrae variable with a $0^{d}.5497$ fundamental and $0^{d}.4101$ first overtone periods simultaneously excited (Wenzel, IAU Colloq. 29, Part II. 221; Jerzykiewicz and Wenzel AcA 27. 35).

9. VARIABLE STARS IN GALACTIC GLOBULAR CLUSTERS (H.B. Sawyer Hogg)

A. Introduction

Since the last report was prepared for the I.A.U. in 1976 more than a hundred papers have been published dealing with variables in more than two dozen galactic globular clusters. Obviously these can not all be discussed. The more significant results are summarized, with author's name and date. This will make easy access to the reference and summary in Astronomy and Astrophysics Abstracts. Also the writer is planning to publish the Fourth Catalogue of Variable Stars in Globular Clusters (David Dunlap Observatory Publications, vol. 3, No. 8) in time for the I.A.U. in 1979, with a full set of references.

A valuable and comprehensive review of the subject by L. Rosino appeared last summer in Vistas in Astronomy, volume 22, part 1, pp. 41-74 (1978). With 19 tables, 15 figures and more than a hundred references this paper brings us up to date with information available into 1977.

B. New Variables and New Periods (See also Binaries, X-ray clusters, Omega Centauri)

We draw attention especially to the following clusters, with considerable data or work: NGC 1261, 2419, 4833, 5986, IC 4499, NGC 6205, 6273, 6356, 6656.

NGC 288, Hollingsworth and Liller (1977) one new variable, RR Lyrae period; 362, Lloyd Evans (1977, 1978, letter) one new, P 130d; 1261, A. Wehlau, Flemming, Demers, C. Clement (1977) 6 new RR Lyrae stars, Wehlau and Demers, (1977) periods for 13 RR Lyrae and one 80 days; 2298, M. Liller (1976) one new variable, periods for 3 RR Lyrae; 2419 Pinto and Rosino (1976, 1977) elements and light curves for 32 RR Lyrae, one cepheid, one red SR; 3201, Lee (1977) 4 new variables; 4833, Demers and Wehlau (1978) 15 RR Lyrae periods, 9 of them new, 2 slow variables; 5272, Kholopov (1977 3 papers) 10 new variables, 2 new RR Lyrae periods, one changing period; 5286 Fourcade, Laborde, Puch, Colazo, Arias (1975) 6 new RR Lyrae periods, M. Liller and Lichten (1978) 2 new variables, 13 periods; 5466, Zinn and Dahm (1976) V 19, P $0^{d}.82$, anomalous cepheid; 5634 M. Liller and Sawyer Hogg (1976) periods of 5 RR Lyrae; IC 4499, Coutts Clement, Dickens and Epps Bingham (1979) periods and light curves for 52 RR_{ab} and 23 RR_{c}; 5897, Samus (1976) UV bright variable, Wehlau and Sawyer Hogg (unpublished) RR Lyrae periods; 5986, M. Liller and Lichten (1978) 7 new variables, 9 RR Lyrae periods; 6121, Lee (1977) 3 new RR Lyrae stars; 6205, Osborn and Fuenmayor (1977), Pike and Meston (1977) suspected red variables; 6235, M. Liller (1977) 3 new variables, periods for 3 RR Lyrae, 2 eclipsing; 6273, Samus (1976) one new variable, C. Clement and Sawyer Hogg (1977) periods for 5 Mira stars, one irr.; 6535, M. Liller and C. Clement (1977) one new variable, 2 RR Lyrae periods; 6638, Rutily and Terzan (1977) periods for 5 Mira stars and 15 RR Lyrae around cluster; 6656, A. Wehlau and Sawyer Hogg (1977) periods for 3 Mira cluster members and 6 probable field Mira's; 6752, Wesselink (1976) period for V, 1.378 days; 6838, Cohen (1977, letter) new red variable; 6934, A. Wehlau and Sawyer Hogg (unpublished) 10 new periods.

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C. Period Changes

In NGC 5024 Goranskij (1976) has studied the period variability of 31 RR Lyraes and shows two types of variability, spasmodic or uneven variations and smooth, unperiodic variations, showing a dependence of period jumps on the period of the variable. In Messier 5 Wilkins (1976) has compared for 65 variables periods from many observers to fix their variations. In the same cluster C. Coutts and Sawyer Hogg (1977) show the 26 day period for the W Vir star V 84 has both increased and decreased markedly, but the similar period of V 42 has barely changed. In Messier 22 A. Wehlau and Sawyer Hogg (1978) have determined period changes for 14 RR Lyraes of which 8 are increasing and 5 decreasing, one with abrupt change. In Messier 15 Smith and Wesselink (1977) studied 12 RR Lyraes which, combined with earlier results show a significant excess of increasing over decreasing periods. Hoffleit (1976) confirms a relation found earlier between period length and abrupt change of period for Pop II Cepheids. Rastorgyev (1978) has compared the period changes of long period cepheids in 9 globular clusters to show that the cepheids with periods less than 10 days have more stable periods than those over 10 days. The time of life in the zone of instability is longer than theory predicts.

D. Red Variables

In addition to red variables mentioned in other sections we draw attention to the work by Eggen (1977) on the MARV and SARV stars in M4, M22, NGC 5897 which lie above the asymptotic giant branches and may be progenitors of halo population long period Cepheids. Mallia (1976) has barium characteristics for 2 red variables in M 22. White (1978) has made a determined hunt for variability of red giant and asymptotic branch stars. He concludes that photometric variability is a more generalized phenomenon throughout these branches than previously thought, with 7 such stars indicated in M 3, 9 in M 13 and 5 in M 15. In M 13 Osborne and Fuenmayor have studied the red variables, with results indicating all red giants redder than (B-V) 1.45 are variable.

E. Binaries

Very few binaries have been found within the area of globular clusters. Those considered for some years to be probably members have been gradually ruled out. Geyer (1965) showed V 65 in NGC 3201 a non-member. Geyer (1978) M. Liller and Lichten (1978) rule out, from velocity V 78 as a member of Omega Centauri. At the Globular Cluster Institute, Cambridge, England in 1978 M. Liller showed the velocity of V 3 in NGC 6838 indicates it is a non-member.

Meanwhile, because of the discovery of some globular clusters as X-ray sources, the hunt for binaries in them has been stepped up. Trimble (1976) conducted a hunt in the core of NGC 6809, but found an apparent absence of faint variable stars. In a further discussion of close binaries in globular clusters, Trimble (1977) following discussion of binaries by Hills (1975, 1976) states that while the number of binaries predicted does not conflict with available data, careful searches would provide a test of theories.

In Omega Centauri Niss, Jørgensen and Laustsen (1978) have conducted a systematic search for eclipsing binaries brighter than the turn-off point. They have found 22 variables (revised number, personal communication) one of which is almost certainly an eclipsing binary).

F. X-ray Clusters

In some clusters known variables lie within the error box of the X-ray source, but apparently no such variable has yet been positively identified as the source. In NGC 1851 Bolton and Mallia (1977) propose as the source a highly evolved star, not variable photometrically, but with radial velocity variation in a 15 day period. In this cluster A. Wehlau, M. Liller, Demers and C. Clement (1978) have periods for 19 RR Lyrae stars, 7 of them new variables. In NGC 6441 Hesser and Hartwick (1976) find that V 6, within the X-ray source error box, has an anomalous position in the C-M diagram. They also not two probable variables. In NGC 6624 M. Liller and W. Liller (1976) have one new variable and (1978) report that red V 3 is a probable member, but the one RR Lyrae star may be a field variable. In NGC 7078 Chu (1976, 1978) reports an ultrashort period variable of a new type, and Leroy (1976) reports that his work on the core has shown some new variables in the center.

G. Cluster Membership

The work on binaries in globular clusters emphasizes the importance of determining the probabilities of membership for variables in the cluster region. Proper motions, radial velocities, color magnitude diagrams in various wavelengths, and statistical probabilities are being used to decide on membership.

Cudworth, (1976) using proper motion in M 92 finds a 99 percent chance of membership for 5 RR Lyrae stars, with V 14 a field star. In M 13 (1978 letter) he has a 99 percent membership probability for 9 variables, with two more very probable. In NGC 6304 Hesser and Hartwick (1976) find that the RR Lyrae stars, even those closest to the center, may be field, but red variable V 15 may be a member.

In Omega Centauri Geyer proves non-membership for the very short period cepheid V 65.

In M 22 Lloyd Evans discusses the positions of 6 red variables on the giant branch.

In useful pieces of work R. Webbink (1978, private communication) has tabulated variables listed in the General Catalogue which are within the tidal radius of various clusters, and J. Nemec (1978 Master's Thesis, University of Victoria) has identified variables in the post horizontal branch stars of 19 globular clusters.

H. Omega Centauri, the most studied cluster

In addition to information in other sections of this report, we note that Freeman and Rodgers (1976) show the chemical inhomogeneity of 15 RR Lyrae stars. Sturch (1976) has photoelectric observations of three RR Lyrae stars confirming metal weakness. Glass and Feast (1977) with J, H, K photometry have classed the red variables as TiO absent or present. Butler, Dickens and Epps (1978) in a spectroscopic study have determined Fe/H values for nearly half the RR Lyrae stars in the cluster, showing a range in metallicity, and finding 2 new variables. The variation in metallicity is confirmed by Sturch (1978) with UBV photometry of 10 RR Lyrae stars. Fourcade, Laborde and Yurquina (1978) have a new long period variable.

I. Correlations

Auverge (1976) made a statistical study of RR Lyraes in 12 globular clusters with special reference to the period amplitude plane. Cacciari and Renzini (1976) present a graphical catalogue of RR Lyrae variables with numerous correlations. Samus (1976) discusses the relation between transition period and luminosity of RR Lyraes in globular clusters. Wilkens (1976) has derived the diameters of 66 globular clusters from their variables and Innanen and O'Brien (1977) studied the ellipticities of RR Lyrae systems in these clusters. Pike (1976) suggests NGC 6366 provides a chance to determine the absolute magnitude of a metal rich RR Lyrae. Gingold (1976) discusses the evolutionary status of Pop II cepheids with theoretical diagram of period distribution. In M 13 the mass of V 1 has been calculated by Osborn and Rosenzweig (1976), and by Pike and Meston (1977) in their improved colour photometry of the cepheids and RR Lyrae stars. Eggen (1977) in a classification of intrinsic variables from UBV and RI observations has derived parameters for long period cepheids in four globular clusters. In M 4 Smith and Butler (1978) show no star--to-star range in metallicity for the RR Lyrae stars, in sharp contrast to those in Omega Centauri.

10. RED VARIABLES (M.W. Feast)

The study of red variables is being pursued actively at the present time. This is very largely because new techniques (e.g. microwave work, infrared studies and diameter determinations) have revealed new phenomena and offer the possibility of deepening very considerably our knowledge of these stars. During the past three year period the accumulation of basic data has continued (e.g. UBVRI of Medium Amplitude Red Variables, Eggen, Ap.J. Supp. 34, 233, Ap. J. 213, 767, UBV of Miras, Celis A.A. Suppl. 29, 15, A.A. 63, 53. Discovery of Mira Variables etc. Rosino and Guzzi, A.A. Suppl. 31, 313, Friedemann et al. A.N. 298, 327, JHKL (Infrared) Photometry of Mira and other Variables Feast et al. (SAAO). Much remains to be done in this field if the statistical properties of the variables are to be properly studied and if the variables are to be used for studies in galactic structure (and also in the Magellanic Clouds). Consideration needs to be given to the completeness of discovery in various regions. In planning further photometric work considerable care will be needed in choosing the most effective wavebands (including band widths) at which to work.

Speckle interferometry opens up the exciting prospect of detailed studies of the diameters of Mira Variables and their variation with phase and wavelength. Variations of diameter by a factor of two are found for wavelengths inside or outside strong TiO bands (Labeyrie et al. Ap. J. 218, L75, 1977). Evidently not only the pulsation but much of the detailed structure of the atmosphere will eventually be studied by this method. The extent of circumstellar shells round Miras is indicated by the discovery of an optical emission region several arc seconds in size round R Leo (Lambert and van der Bout, Ap. J. 221, 854). Another powerful new tool, heterodyne interferometry, has been used to study the spatial structure of circumstellar shells of red variables at 11 microns (Sutton et al. Ap. J. 217, L97, 1977). In a different approach Barnes and Evans (M.N. 174, 489, 1976) have derived a relation between the V-R colour and surface brightness and applied it to the case of Mira Variable pulsations. Low resolution scans of Mira Variables in the infrared (Strecker et al. A.J. 83, 26, Puetter et al. P.A.S.P. 89, 320) also allow colour temperatures and diameters to be deduced. In addition they will be useful in interpreting broad band infrared colours of Miras.

Improved absolute magnitudes for Mira Variables remain an outstanding need. Work on statistical parallax etc. of Miras for infrared absolute magnitudes is in progress at SAAO. Eggen (P.A.S.P. 88, 715, 1976) has derived space motions for some Miras. However his absolute magnitude calibration is not in agreement with that of others. Aslan (Obs. 96, 149, 1974) has derived absolute magnitudes for SR Variables in groups whilst Upgren (A.J. 80, 828, 1974) has removed a number of discrepant parallaxes. Absolute Magnitudes for Miras have been predicted semitheoretically by Cahn and Wyatt (Ap. J. 221, 163) and it will be important to compare these predictions in more detail with observations.

Polarization studies hold out very considerable promise in understanding Mira Variables, especially when the results are combined with other work. It is known that Mira Variables with high polarization also have infrared excesses indicating circumstellar shells. However studies of time variability etc. suggest that the polarization occurs much closer to the star than the infrared excess. The increase in polarization in at least some Miras at phase ~ 0.8 when emission lines first appear suggests the formation of particles in a shock wave in the atmosphere (c.f. Coyne and Magalhaes A.J. 82, 908, Shawl A.J. 80, 602, Kruszewski and Coyne A.J. 81, 641, Materne A.A. 47, 53, 1976). Shawl has discussed the polarization of Mira Ceti B which may indicate that a significant amount of the polarization of Mira A and B comes from a (common) circumstellar envelope. Mira B will certainly interact physically with such an envelope. Further light on this problem could well come from polarization work on symbiotic stars. The red star in these binary systems is either an M giant or a Mira (Feast et al. M.N. 179, 499). Extensive polarization work on these systems especially those with Mira components would be valuable for the general Mira problem. The OH and H_2O microwave emission from Mira variables may be anomalous in binary systems (c.f. Lepine et al. A.A. 56, 219) indicating a shell affected by the companion. In this connection it is worth noting that R Car which has anomolously weak H_2O (Lepine et al.) is a member of a binary system (Obs. 90, 25). Narrow band polarization work on Miras has recently produced some very important results (Landstreet and Angel Ap. J. 211, 825, McLean and Clarke M.N. 179, 293, McLean M.N. 1978, McLean and Coyne Ap.J. 1978). These observations show changes in percentage polarization and/or position angle across strong spectral features. This indicates that at least some of the polarization arises in the stellar atmosphere. However, the results obtained so far are quite complex, e.g. a decrease in polarization across a strong TiO absorption band in Mira Ceti but increased polarization across some ZrO bands in R And (with, in one band, an increased polarization at one time and a decrease at another). McLean and Coyne find a very high polarization (6.8%) of Hβ emission in Mira Ceti just before maximum. This could either be intrinsic (due for instance to emission phenomenon in a shock front) or produced within the stellar atmosphere (due to the large depth at which Hβ is emitted at that phase).

Some progress has been made with spectroscopic analysis of red variables (e.g. the C^{12}/C^{13} ratio in the Se variable χ Cyg (Hinkle et al. Ap. J. 210, 684) and in the SC star UY Cen (Catchpole, Leige 1978). Further work will undoubtedly be done on element and isotope abundances in red variables and should lead to a clearer understanding of evolutionary processes and mixing mechanism in these stars. C, N, O abundances relevant to Miras are discussed by Eggleton (Q.J. 17, 448) and Lequeux (A.A. 43, 71). An important spectroscopic result is the extreme phase dependency of SiO (4μ) absorption. This could indicate a chromospheric contribution to the infrared continuum and will obviously be studies further in more detail. The proper understanding of the role of TiO opacity remains of great importance. The problem has been studied theoretically by Krupp et al. (Ap. J. 219, 963). Maehara (P.A.S. Jap. 28, 135) has attributed line weakening in Miras to TiO opacity. The discovery that many red variables (especially Mira stars) are 18 cm OH emitted has given a very large impetus to the study of these stars. There is a need to know more about how OH emission is related to other properties of the variable and recent surveys of red variables for OH have been made by Kolena and Pataki (A.J. 82, 150) and Fix and Weisberg (Ap.J. 220, 836). Many OH sources can be recognised as probably very long period Mira stars from their 18 cm structure. These OH/IR sources are of great importance for galactic structure problems.

Amongst recent 18 cm surveys have been, Bowers (A.A. Suppl. 31, 127, A.A. 64, 307, 1978), Johanson et al. A.A. Suppl. 28, 199, A.A. 54, 323, Baud (Thesis, Leiden 1978). Some of the problems of these stars were reviewed at the 1977 Bamberg Variable Star Colloquium. Most OH/IR sources appear to be relatively young objects concentrated to the galactic plane. However, the nature of the OH sources near the galatic centre remains rather enigmatic. Work on optical Miras in the galactic centre is important for comparison with these OH sources cf Lloyd Evans M.N. 174, 169, Glass (infrared), Feast (radial velocities) in progress. Since the OH/IR sources are expected to be cool and/or heavily reddened objects they are best searched for optically in the infrared. In order that such search can be carried out successfully it is necessary to have good OH positions (e.g. Evans et al. Ap.J. 206, 440, 1976, Winnberg et al. A.A. 38, 145). So far there has been some success with finding IR candidates (e.g. Schultz et al. A.A. 50, 171 and 52, 475, Evans and Beckwith Ap.J. 217, 729, Glass M.N. 182, 93). However it is necessary to monitor these IR sources to establish them as (Mira) variables and to determine their periods. Schultz et al. (A.A. 63, L5) find that the 18 cm emission in some OH/IR sources has a phase lag in intensity between the two components of the emission line. Since the double emission components are usually interpreted as coming from the front and back of an OH shell they are able to calculate a shell diameter ($\sim 10^{16}$ cm). Clearly an extensive investigation of this idea would be very valuable. Simultaneous infrared light curves would also be useful to determine the way the OH intensities are related to the energy output of the star. A programme along these lines has been arranged between the Leiden Observatory and SAAO Cape. The integrated OH flux probably has little or no lag relative to the infrared flux (Fillit et al. A.A. 58, 281). In understanding Mira Variables it would be very useful to have some optical parameter which distinguished OH from non--OH Miras. Bowers and Kerr (A.A. 39, 473, A.A. 57, 115) find that the visual rise time is such a parameter at least statistically. This seems a valuable clue to a relation between the stellar pulsation and the OH intensity.

A detailed study of the structure of OH emitting red variables has been made by Reid et al. (Ap. J. 196, L35, 214, 60). Quite complex structures are evident. Both they and Fix (Ap.J. 223, 225) show that the OH maser lines are saturated. Reid et al. discuss a de-

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tailed model for OH masers (see also Elitzur A.A. 62, 305, Burdjuzha and Ruzmaikina A.A. 40, 233 Kwok J.R.A.S. Cand. 70, 49 Deguchi P.A.S. Jap. 29, 669, 1977. Olnon. Thesis Leiden 1977).

The discovery of other molecules in the microwave region (i.e. H_2O and SiO) together with OH and infrared observation allows us to make progress in studies of the detailed structure of the circumstellar shells of Miras. A good deal of work has gone into the discovery of microwave emitting Mira variables (e.g. H_2O sources, Lepine et al. A.A. 48, 269 Dickinson, Ap.J. Suppl. 30, 259, SiO sources A.S. 65, L7, Dickinson et al. A.J. 83, 36, Spenser A.J. 82, 706. and CO sources (Zuckerman et al. Ap. J. 211, 297, Lo and Bechis, Ap. J. 218, L27, Lambert and van der Bout, Ap. J. 227, 854). In the case of H_2O there is a double emission similar to that seen in OH but with smaller separation (Dickinson and Kleinmann, Ap. J. 214, L135). Blair and Dickinson (Ap. J. 215, 552) find that H_2O sources are much less frequent amongst S than M type Miras, due probably to the higher C/O ratio in the S stars. SiO microwave luminosity of Miras appear to be correlated to the period (Cahn Ap. J. 212, L135) though there is still some doubt about this (Dickinson et al. A. J. 83, 36) which will only be resolved by further observations.

Studies of the time variations of the microwave components will no doubt be carried out. The results presently available are rather tentative e.g. for Sio, probable variation of some Miras related to the light variation (Spenser et al. Ap. J. 199, L111) but in other Mira variation in a time scale of a few days (Balister et al. M.N. 180, 415). In some Miras non-maser SiO emission has been detected and its excitation has been discussed in detail by Morris and Alcock (Ap. J. 218, 687). A problem with the interpretation of H_2O microwave emission has arisen through the work of Wallerstein et al. (P.A.S.P. 89, 391). Working at 9400 A they fail to detect H_2O absorption in several Miras and deduce a much lower H_2O abundance than is required by current theories of H_2O masers.

It has been established by Reid et al. (Ap. J. 207, 784, 209, 595, 220, L113), that the true stellar velocities of Miras is mid-way between the two OH velocity components. Reid's work shows that this can be reconciled with optical results. He finds the interesting result that the "K" term derived using optical emission lines and a solution for galactic motion of Miras is different for those stars with measured absorption line velocities and those without. The most straightforward explanation of this is that it is related to the uncertainty in the phase at which optical observations were made, these being particularly uncertain for the fainter variables. The poor ephemerides coupled with the fact that emission lines are more difficult to detect before maximum than after could bias the optical sample to a mean phase somewhat after maximum. Since the emission velocity tends to decrease after maximum light, this would lead to the observed ffect. A more thorough investigation of this point might be useful. Whilst these results now considerably simplify the problems of model making so far as the shell is concerned they leave a number of problems still to be investigated, particularly; how are the optical absorption and emission velocities related to the OH velocities? Now that the stellar velocity can be defined from microwave observations the detailed study of optical velocities (both emission and absorption and in all spectral regions) becomes much more worthwhile since their interpretation should be considerably eased. The problem will require very extensive observations, as for istance the work of Wallerstein (Ap. J. Suppl. 29, 375) indicates.

11. THEORY OF STELLAR PULSATIONS (A.N. Cox)

This review deals with ten topics grouped in the two main headings: the interpretation of specific observations and theory with a general application. The purely observational aspects of red variables, Cepheids, RR Lyrae variables, β CMa variables, δ Ceti variables and dwarf Cepheids, and variable white dwarfs (ZZ Scuti variables), all of which pulsate, will be found elsewhere in this commission report. Not all references are given because this review is not a complete study of all pulsation theory but only of selected topics. Even for these selected topics the references are not necessarily complete.

We first consider the pulsation of our sun. The observations of Hill, Stebbins, and Brown seem to indicate that there are small amplitude variations in the position of the edge of the solar disc with periods of from 6 minutes to over an hour. The best reference to these data and a discussion of their significance is Brown, Stebbins, and Hill (Proceedings of the Solar and Stellar Pulsation Conference, Los Alamos LA-6544-C and 1978 Ap. J. 223, 324). These variations of only a few milliseconds of arc, a few kilometers in the solar diameter, have led to great arguments over whether they are real. This is especially so because different techniques of measuring these oscillations give very different results.

Severny, Kotov, and Tsap (1976, Nature 259, 87) and Kotov, Severny, and Tsap (1978, MNRAS 183, 61) at the Crimea Astrophysical Observatory have discussed an observed period between 120 and 180 minutes bydetecting Doppler shifts of the solar FeI line at 5123.7 A at the solar center relative to the outer rim. Their earlier periodic fluctuations in the radial velocity of the sun at 160 minutes were confirmed by Brookes, Issak, and van der Raay (1976, Nature 259, 92) who found two more periods of 40 and 56 minutes. However, Fossat and Ricort (1975 Ast. Ap. 43, 243), Grec and Fossat (1977, Ast. Ap. 55, 411), and Fossat, Harvey, Hausman and Slaughter (1977, Ast. Ap. 59, 279) could not confirm any of these periods with a sensitivity of better than one meter per second using similar radial velocity measurements of the sodium D line. They attribute the periods greater than 10 and less than 90 minutes to terrestrial atmospheric effects, and the maximum solar radial velocity is less than 1 meter/s, much smaller than the implied Hill value of about 40 m/s. Livingston, Milkey, and Slaughter (1977, Ap. J. 211, 281) find no fluctuations for periods longer than 5 minutes by observing the CI line depth which should be a temperature and luminosity indicator. Worden and Simon (1976, Ap. J. 210, L163) suggest that the 160 minute oscillations are due to the rotation of large scale solar velocity cells (supergranulation) ghrough the field of view of the detectors. Gough, Pringle, and Spiegel (1976 Nature 264, 424) suggest supergranule seiching may produce this 160 minute period. These sources of error have been discussed by Kotov, Severny, and Tsap and found not applicable.

The five minute oscillations of Leighton and Noyes are a completely different matter. They have been measured and interpreted extensively. The recent results of Deubner (1976, Proc. IAU Colloq. 36) and Rhodes, Ulrich, and Simon (1977, Ap. J. 218, 901) have been discussed in detail by Ulrich and Thodes (1977, Ap. J. 218, 521) who have been able to determine reasonably well the structure of the solar convection zone and how it oscillates in nonradial modes. The rotation of the outer solar layers as it decreases inward at first and then increases at depth is now being mapped using these short period oscillations.

Hill, Rosenwald, and Caudell (1978, Ap. J. 225, 304) have argued that the longer period very low amplitude oscillations are not so readily visible in measurements of the Doppler shifts of spectral lines or of intensity changes in the continuum and spectral lines. This conclusion which is based on linear theory solutions for eigenfunctions in the very uncertain outer layers of the sun, could also explain the lack of temperature fluctuations reported by Hill, Livingston, and Caudell (1977, Ap. J. (Letters) 214, L137) for the 5 minute oscillations and the lack of photospheric luminosity variations observed by Mussman and Nye (1977, Ap. J. (Letters) L95) and of Ca II K line variations reported by Beckers and Ayres (1977, Ap.J. (Letters) 217, L69).

The current situation regarding the longer period solar oscillations is confused. Three series of new limb observations obtained separately by Hill, Brown, and Stebbins seem to confirm the longer period oscillations (certainly one at 21 minutes) whereas disc observations do not. Dittmer (1978, Ap. J. 224, 265) sees no periodicity between 7 and 70 minutes in the Fe I 5123.7 line radial velocity. Detailed predictions of a large number of solar radial and nonradial mode periods are available (Christensen-Dalsgaard, and Gough (1976, Nature 259, 89), Iben and Mahaffey (Ap. J. 1976 (Letters) 209, L39), Goldrich and Keeley (1977, Ap. J. 211, 934), (1977, Ap. J. 212, 243), Rouse (1977, Ast. and Ap. 55, 477), but reconciliation among the various observations and between theory needs much further discussion.

The most understood pulsating star class, the Cepheids, has had a problem of uncertain masses. Evolution theory has consistently predicted that Cepheids are 3.5 - 18 $M_{\odot}$ stars core helium burning on blue loops in the H-R diagram. Recent tracks are given by Carson and Stothers (1976, Ap. J. 204, 461) and Lamb, Iben, and Howard (1977, Ap. J. 207, 209). Any mass loss more than 10 percent supresses the blue loops which have been discussed by Lauterborn, Refsdahl, and Roth and recently by Durand, Eoll, and Schlessinger (1976, M.N.R.A.S. 194, 671) and by Schlessinger (1977, Ap. J. 212, 507). Sreenivasan and Wilson (1978, Ast. Sp. Sci. 53, 193) have verifid the mass loss suppression at 15 $M_{\odot}$. Thus Cepheids should have masses (M_{ev}) given by the evolutionary theory mass-luminosity relation with no mass loss (Becker, Iben, and Tuggle (1977, Ap. J. 218, 633)). In extreme cases Buchler (1978, Ap. J. 220, 629) finds that pulsation might affect the evolution tracks, however. For 16 Cepheids with known distances, the known luminosity can give a mass which ranges from 4.8 to 12.4 $M_{\odot}$. These same Cepheids also have measured unreddened colors which can be converted to surface effective temperatures to evaluate radii. A period and radius used in the Eddington period mean density relation gives a pulsation mass which has been anomalously low until recently. Now new larger distances (Hanson, 1977 IAU Symposium 80) to the clusters with Cepheids and better unreddened colors give larger luminosities, radii, and masses, eliminating this pulsation mass anomaly.

There are, however, other mass problems with those Cepheids with bumps in their light and velocity curves and those which simultaneously display more than one pulsation mode, the double-mode or beat Cepheids (Cox and Cox, 1976 IAU Colloquium 29). For most of the Cepheids in these two classes. the luminosity is not known and, therefore, no evolution theory mass is available. However, use of the evolution theory mass-luminosity relation, the period-mean density relation, the linear theory pulsation constants (Q) for the proper pulsation mode, and the relation between luminosity, radius and T_e, one can solve for M, R, L, Q using only an observed period and an approximate T_e. The mass so obtained, termed a theoretical mass (M_T), is never more than 20 percent different from the evolution mass for those known ones. This theoretical mass used as a stand-in for the evolution mass allows quantitative comparisons of the ratio of the bump or beat masses with M_{ev}.

Bump masses are those derived from nonlinear hydrodynamic integrations which require anomalously low mass to predict the proper observed Hertzsprung relation between bump phase and period. The beat masses come from linear theory predictions that the ratio of the two periods is mass dependent. While the bump masses are low by a factor of almost two, the beat masses are as low in some cases as a factor of four.

Simon and Schmidt (1976, Ap. J. 205, 162) have indicated a method of getting bump Cepheid masses using only linear theory. The ratio Π_2/Π_0 of the second overtone to fundamental periods is correlated with nonlinear theory bump phase, being 0.53 for shorter period Cepheids with the bump far down on decreasing light and 0.46 when the bump is very early on rising light. At a given period the period ratio Π_2/Π_0 is obtained only for low masses of homogeneous models. Petersen (1978, Astr. and Astrophy. 62, 205) gets very low beat Cepheid masses by using the values of Π_1/Π_0 and log Π_0 on a theoretical plot of these two linear theory quantities with stellar mass as a parameter.

Cox, Michaud, and Hodson (1978, Ap. J. 222, 621) have shown that if a helium deficient Cepheid wind can enrich the helium content in the outer convection zones containing only 10^{-4} of the mass, the Cepheid bump phases, predicted from linear theory, and the beat Cepheid period ratios again from linear theory, can be made consistent with masses that are like the theoretical masses. Since the periods change only 5-10, percent the pulsation mass, and a mass obtained for some Cepheids from Wesselink radii (Balona, 1977, MNRAS 178, 231 and Evans, 1977, Ap. J. 209, 135), are only slightly changed. These inhomogeneous models seem to fit the available data, though their spectra might show some slight effects of the large helium (Y = 0.75) content. The principal problem with the enhanced helium is its instability against downward mixing. A little downward flow, however, has been used by Cox. King, and Hodson (1978, Ap. J. 224, 607) to explain the three simultaneous periods seen in AC And.

Other ideas about the beat Cepheid mass anomalies have been published by Cogan and Faulkner. Cogan (1977, Ap. J. 211, 890) proposes very extensive convection zones which can change the structure in the outer layers changing the Π_1/Π_0 period ratio. Deupree (1977, Ap. J. 215, 232) has found such large convection is unlikely. Faulkner (1977, Ap. J. 216, 49) proposes that the coupling between the fundamental and first overtone modes changes their ratio, but Cox, Hodson, and King (1978, Ap. J. 220, 996) found that the linear theory periods are only slightly changed in nonlinear calculations and presumably in real Cepheids.

Faulkner (1977, Ap. J. 218, 209) in a study of the periods of the double-mode Cepheid TU Cas. announced the occurrence of a third period, the second overtone. This has not been confirmed by Hodson, Stellingwerf, and Cox (1979, Ap. J. 229, 000) but the amplitude of the first overtone was found to be decaying from 0.4 to 0.25 mag. Faulkner has now found that another double-mode Cepheid, U Tr A seems to have a growing first overtone amplitude. These amplitude change rates are about as predicted by Stellingwerf in 1975, but the large number of double-mode Cepheids has led Stobie (1977, MNRAS 189, 631) to suggest that their double-mode life is as large as one third of their life as Cepheids.

Dwarf Cepheids show double-mode behavior also. Simon (1979, Astr. Astroph., in press) has discussed the observational data of AI Vel and has proposed, as others before, that its mass is like 0.4 $M_{\odot}$. Stellingwerf (1978, Ap. J., in press) was able to get the observed period ratios using modern opacities whereas previous studies go the ratio too low for masses 1 - 2.5 $M_{\odot}$ expected for normal evolution tracks. Cox, King, and Hodson (1979, Ap. J. 229, 000) then derived theoretical masses for 9 of the dwarf Cepheids. SX Phe has a mass of 1.1 $M_{\odot}$ with $Z = 0.001$, as observed, and a decreased $Y = 0.1$ in the surface layers due to downward settling and some remixing discussed by Vauclair (1976, Astr. Astroph. 50, 435 and 1977, Astr. Ap. 55, 147). The idea that SX Phe is very old near the main sequence after a mass loss as a red giant has been pursued by Saio and Takeuti (1978, PASJ, in press).

The question then of whether the stars which show metallicism can pulsate was addressed by Valtier, Baglin, and Auvergne (1979, Astr. Ap., in press) and by Cox, King, and Hodson (1979, Ap. J., in press). The two papers disagree on how the pulsation can occur, the first paper suggesting that hydrogen alone causes the driving and the second alleging that there is enough residual helium after the lower convection zone, and its severe mixing effects, disappears to cause the pulsation in at least the red third of the δ Scuti instability strip.

Turning now to general theory we consider first the problem of calculating full amplitude pulsations. Since the last IAU General Assembly it appears that only three nonlinear calculations have been published apart from the 2D convection studies by Deupree. The bump Cepheid problem for a 10 day homogeneous composition Cepheid has been calculated by a dynamically zoned mesh program and published by Davis and Davison (1977, Ap. J. 221, 929). Vemury and Stothers (1978, Ap. J. 225, 939) considered the pulsations of homogeneous composition Cepheid models using the unpublished opacities of Carson. Bumps at the correct phases were found with the expected evolution theory masses at amplitudes just a bit larger than for actually observed Cepheids. Opacity variations (mostly due to helium) between 25,000 and 100,000 K which are different from those in the Los Alamos opacities (Cox and Tabor 1976, Ap. J. Suppl. 31, 271), seem to cause the bumps. The accuracy of these calculations depends on the accuracy of the Carson opacities which are still being questioned.

Nonlinear calculations of Cox, Hodson, and King (1978, Ap. J. 220, 996) address the even more difficult question of modal selection. Use of the Baker-von Sengbusch-Stellingwerf relaxation method to get strictly periodic full amplitude solutions has resulted in a situation where no double-mode behavior can now be predicted except for mode switching at the transition line between the fundamental and first overtone modes. In principle, if one could find two full amplitude periodic solutions which, by linear analysis, tend to decay to each other, then double-mode behavior should occur. Searches for the physics of this behavior are continuing.

One hopeful idea about what causes bumps and double-mode pulsations has been discussed by Simon (1977, Ap. J. 217, 160; 1978, Astr. Ap., in press). The Cepheid light curve bumps discussed earlier in this review could be a resonance between the fundamental mode and the second overtone, possibly even when the second overtone is not unstable in the linear theory. Double-mode Cepheids are predicted to occur when the interaction frequency which is the sum of the fundamental and first overtone frequencies is resonant with the third overtone. Double-mode dwarf Cepheids are predicted to occur when this sum frequency is resonant with the fourth overtone. Some application of these ideas is being published by Simon and Cox, but there has been some problem of finding the resonance for nonlinear periods which differ a percent or so from the linear theory ones.

Another idea about the double-mode Cepheids has been suggested by J.P. Cox in his review of Cepheids at the Goddard Conference on stellar pulsation instabilities. Perhaps there is a small admixture of nonradial modes in these variables to alter the period ratios just enought to imply anomalously small masses. Osaki (1977, PASJ 29, 235) and Dziembowski (1977, Acta Astronomica 27, 95) have shown that nonradial p mode pulsations with $\ell \geqslant 4$ can exist in Cepheid and RR Lyrae variables.

Extensive convection calculations for RR Lyrae variables have been made by Deupree (1977, Ap. J. 211, 509; 1977, Ap. J. 214, 502; 1977, Ap. J. 215, 232; 1977, Ap. J. 215, 620) to investigate time dependent convection in two space dimensions. The main result is that the cause of the red edge is a conversion of the hydrogen driving zone to a damping zone when the full amplitude case is considered. Normally, the γ and κ effects operate on the radiative luminosity to phase its flow in order to excite the growth of pulsations. At maximum compression, for example, the luminosity is absorbed locally in the hydrogen and helium ionization zones by a low γ (ionization occurring) and a high κ (reducing energy flow). Then when expansion occurs the energy is released to drive the pulsation. However, the convection in the hydrogen ionization layers is so strong that it actually produced more luminosity at maximum compression and causes pulsation damping.

Gough (1977, Ap. J. 214, 196) discusses the linear theory pulsation with convection.

With red edge data for both the fundamental and first overtone modes Deupree has considered the width of the RR Lyrae strip as a function of helium content. Even though the blue edges, as mapped by Iben and Tuggle in 1972 and Cox, King, and Tabor in 1973, indicate, a helium mass fraction Y of between 0.20 and 0.25, the total width, which is independent of reddening corrections, indicates Y between 0.25 and 0.30. Evolution theory in comparing the relative life times in the red giant and horizontal branches to the relative numbers observed in these H-R diagram regions suggest a Y of 0.25 or less, according to 1972 results of Demarque, Mengel, and Sweigart. This dilemma of why the red edge is predicted a bit too hot, making the strip too narrow for Y = 0.25 in Deupree's convection calculations, is being investigated.

Another convection result, not directly related to pulsation, is a recipe for the ratio of mixing length to pressure scale height given by Deupree (1977, Ap. J. 215, 620) for use in 1D models of pulsating stars.

A general theoretical result has been given by Renzini and Swigart (in press) to explain the positive and negative period changes for RR Lyrae variables. The semiconvection that seems to occur in the nuclear burning core of these horizontal branch popula-

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tion II stars might adjust itself in small jumps. These changes in the central structure cause a change in the radius of the model which then changes the period. The average rate of change of the period is given by the rate of evolution along the H-R diagram track, but both positive and negative radius and period changes of the sizes observed can occur as the semiconvection adjusts itself.

Mira variable pulsations have been studied in the presence of mass loss. The earlier calculations of Wood (1975) showed that Miras were pulsating in the first overtone mode; the fundamental mode is dynamically unstable. Hill and Wilson (1979, Ap. J., in press), however, think that observations indicate fundamental modes. At lower masses, however, Keeley earlier did get fundamental modes. Wilson (1976, Ap. J. 205, 172) and Slutz (1976, Ap. J. 210, 750) have discussed shock waves which probably produce a puff of mass loss at each pulsation cycle. More details are given by Willson and Hill (1979, Ap. J., in press). The fate of the red giants as they lose mass has been discussed by Wood and Cahn (1977, Ap. J. 211, 499). They predict that stars with masses up to 4.5 $M_{\odot}$ become Mira variables or planetary nebulae and avoid being supernovae. Further work has been reported by Cahn and Wood (1978, Ap. J. 221, 163). Wood has reviewed this work at the Goddard stellar pulsation instability conference, and he has shown that the multiple shocks differ from the single shock of Slutz and cannot cause appreciable mass loss.

12. FLARE STARS (P.F. Chugainov)

Important progress has been made in investigations of individual flare stars and those which are contained in stellar aggregates as well as so called BY Draconis stars (that is, variables showing flare activity and slow quasi-periodic light variations). Current problems have been discussed at the Symposium held in 1976 in Bjurakan Observatory (see "Flare Stars", Armenian Academy of Sciences, Erevan, 1977). Review papers have been published by Mullan (Irish AJ, 12, 162; 12, 278), Gurzadyan (ASS. 48, 313) and Mirzoyan (IAU Coll. 42, 106).

New flare stars of UV Cet-type have been discovered by Bond (IB, 1160), Lovas (IB, 1345), Veeder and Hansen (IB, 1266), Byrne (IB, 1407). Photoelectric observations of known stars of this type are reported by Jarrett and Gibson (IB, 1105, 1112), Sanval (IB, 1180, 1210), Contadakis et al. (IB. 1181), Slovak (IB, 1271), Hansen and Veeder (IB, 1292), Kareklidis et al. (IB, 1354, 1355, 1356), Ichimuza and Schimizu (Tokyo Astr. Bull. No. 255). Some conclusions from the study of UV Cet, YZ CMi and AD Leo at the Uttar Pradesh Observatory in 1971-75 are made by Sinvhal and Sanval (IB, 1263). Photoelectric observations of the double flare star EQ Peg with the area scanner are presented by Rodono (AA, 66, 175). The relation between ultraviolet, red and infrared amplitudes of flares of EV Lac and UV Cet has been investigated by Kilyachkov and Shevchenko (Letters to AZ, 4, 224). 32 flares of EV Lac and 89 flares of UV Cet were observed in the U, 7100 and 8050 A filters. It is found that the flares in the red and infrared are preceded by decrease of the star light in 1/3 of cases.

Results of coordinated X-ray, optical and radio observations of YZ CMi have been discussed by Karpen et al. (ApJ, 216, 479, see also Ap. J. 225, L35). The upper limit of the ratio of soft X-ray to B-band luminosity during the flares is obtained and it is shown that the flare stars contribution to the diffuse X-ray background is negligible. Simultaneous radio and optical observations of UV Cet-type stars are reported by Spangler and Moffett (ApJ, 203, 497). The relationship is studied between the radio emission at two frequences (196 and 318 MHz) and 62 optical flares most of which were weak. In the previous studies this relationship was investigated mostly for large optical flares. Davis et al. (Nature, 273, 644) have worked out the new method of measurement of the radio emission (408 MHz) from flare stars based on use of the interferometer. In December 1977 two radio events on YZ CMi were recorded by them. Moffett at al. (PASP, 90, 93) have made a search for centimetric wavelength emission from flare stars. The upper limit of 1420 MHz emission during a typical flare is found.

In the paper of Mirzoyan at al. (Af, 13, 205) are presented photographic observations carried out mainly in 1973-74 and the discussion of all relevant data on flare stars in the Pleides. The paper is the fifth of this series. In previous papers the distributions of flare stars according to the number of observed flares were represented by the sum of two Poisson distributions. Nevertheless the authors conclude that observations accumulated to the present time can be better represented by the Poisson distribution with a continuous function of flare frequences of stars. This means that large differences are now revealed in activity of the Pleiades flare stars. In the other work Mirzoyan and Ohanian (Af, 13, 561) have shown that in the period 1957-1975 only one half of the low luminosity probable members of the Pleiades possessed flare activity. This conclusion contradict the previous conclusion made by Mirzoyan at al. that all or almost all members of Pleiades with V $\geqslant$ 13.3 are flare stars. However Mirzoyan and Ohanian have presented some evidences that this discrepancy can be explained on the assumption of cyclic recurrence of the flare activity in the low luminosity Pleiades stars. Results of the study of flare stars in several stellar aggregates (including Pleiades, Orion, Cygnus and other) have been surveyed by Haro (Bol. Inst. Tonantzintla, 2, 3) and by Ambartsumian and Mirzoyan ("Flares Stars", p. 63, Erevan) from the point of view of an observational approach to stellar evolution.

Observations of BY Draconis stars provide much information about the physical properties of active regions on stellar surfaces and the nature of flare activity as well. Now in common use is the idea that quasi-periodic light variations reflect the rotation of these stars and are caused by spots. Bopp and Fekel (AJ, 82, 490) have shown that relatively rapid rotation ($V_{rot} \geqslant 5$ km/sec) is the necessary condition for the ocurrence of BY Dra phenomenon. Direct evidences have been presented by Bopp and also by Chugainov (ICAO, 55, 85; 56, 24), Anderson et al. (ApJ, 216, 42), Walker (PASP, 89, 874) and Rucinski (PASP, 89, 280) that rotational velocities of these stars are in agreement with their photometric periods and at least some representatives of this group are young contractive stars.

Survey of the BY Draconis phenomenon has been undertaken by Bopp and Espenak (AJ, 82, 916). 22 dwarf K-M stars are studied and light variations on a time scale of several days are found in 9 of them (Gl. 15B, 176, 182, 277A, 494, 867A and BD+48^{o}1958). It is concluded that variations of two kinds exist, periodic and unperiodic as well. The later kind of variation was observed in two late-type Me-stars (Gl. 15B and 277A). Probably unperiodic variations are due to the growth and decay of active regions near the rotational pole. Quasi-periodic light variations are found by Chugainov (ICAO, 54, 89; 61, in press) in dG-dK stars ξ Boo, BD+30^{o}448, BD+27^{o}4642 and HD 1835 and by Busko et al. (IB, 1275) in dM3e star CoD-38^{o}11343. BD+30^{o}448 and BD+27^{o}4642 showed also some evidence of flare activity. Photoelectric observations of known BY Dra stars have been obtained by Davidson and Neff (ApJ, 214, 140), Bopp et al. (IB, 1443), Chugainov (ICAO, 54, 85). Oskanyan et. al. (ApJ, 214, 430) confirmed the existence of variations of the photometric period of BY Dra and conclude that at the present time light variations of this star are caused by bright spots. Contrary, Chugainov (ICAO, 54, 85; 54, 89) from observation of colour variations concludes that only dark spots present on BY Dra and on other three stars of this type. Different amplitudes of colour are found by Chugainov from one star to another corresponding to the temperâture differences between photospheres and spots from 400 k to 1400 K. A similar conclusion is made by Bopp and Espenak (AJ, 82, 919) from their observations.

The flare activity of BY Dra variables AU Mic, HDE 319139, CC Eri, TW PsA and AT Mic together with their quiscent variability has been studied by Busko and Torres (AA, 64, 153). Considerable change in flare activity of AU Mic between 1970 and 1974 is found. The known relation is confirmed that larger flare durations correspond to higher star luminosities. The mean level of flare activity of the stars studied, with the exception of TW PsA, corresponds to about 1% of the bolometric star luminosity which is a typical value for usual flare stars. Further continuous observations are desirable for TW PsA, a dK5e-star with low flare activity, as well as for other dwarf G-K stars showing quasi-periodic light variations but little known as flare stars.

Much efforts are devoted in order to find out in BY Dra stars the existence of variations in emission lines, particularly those ones which presumably are caused by the rotational modulation. No variations of Ca II K line intensity in BY Dra during the period of rotation has been revealed by Bopp and Ferland (PASP, 89, 69) from precise photoelectric observations; a similar result was also obtained by Fix and Spangler (ApJ, 205, L63). The lack of variation indicate that Ca II emission is uniformly distributed on the surface of BY Dra. However, changes of emission Balmer lines have been observed in BY Dra stars by Ferland and Bopp (PASP, 88, 451), Bopp and Schmitz (in press), Busko et al. (AA, 60, L27). These changes only partly can be attributed to the rotational modulation. Sudden variations of H intensity and (or) profile also exist due to the flares and radial gas movements in envelopes (see Chugainov, ICAO, 57, 31; Hartmann and Anderson, ApJ, 213, L67).

Attempts have been made to detect the magnetic field in BY Dra by means Zeeman observation of the Hα emission line (Anderson, Hartmann and Bopp, ApJ, 204, L51) or polarimetric observations (Koch and Pfeifer, ApJ, 204, L47). Koch and Pfeifer have found variable linear polarization in BY Dra rising toward shorter wavelengths. It is interesting also to note that ξ Boo A in which Merchant Boesgaard et al. (PASP, 87, 353) have observed the variable magnetic field is found to belong to the BY Dra-type (ICAO, 54, 89).

IB = IBVS, Budapest. Letters to AZ = Letters to Astron. Zh.
Af = Astrofizika. ICAO = Izvestia of the Crimean Ap. Obs.

13. NOVAE AT OUTBURSTS (E.R. Mustel and L.I. Antipova)

A large number of papers have been devoted to the V1500 Cyg - the brightest nova during the last 33 years. The amplitude of its outbursts was larger than 19 mag. The character of light variations and the spectral evolution correspond to a fast nova; the MacLaughlin parameter $t_3 \sim 4$ days. The absolute visual magnitude at maximum was

M_o = -10 mag. The expansion velocity of the main envelope was about 2000 km/s. It was noticed (IAU Circ. No. 2839, Chin. Astron., I, 194, 1977) that the brightness of V1500 Cyg increased gradually prior to its outburst. At maximum. a strong uv-excess was observed in the spectrum (IAU Circ. No. 2827). The ultraviolet radiation decreased with time (Jenkins et al., Ap.J., 212, 198) and due to that the bolometric luminosity decreased, as opposed to the case of FX Ser which remained constant during the first 100 days (Jenkins et al., Ap.J., 212, 198, Wu, "Novae and related stars", p. 184). There was no infrared radiation which would indicate the formation of dust around nova (Kawara et al., Pub. Astr. Soc. Japan, 28, 163, Kiselev and Narizhnaya, Astr. Circ., No. 893, 5). The observed polarization is of interstellar origin (Kemp and Rudy, Ap.J., 203, 131, Shenavrin et al., Astron. Zh., 54, 629). The absence of variable polarization also indicates that, unlike the case of other novae, the was no formation of a dust envelope. Within 10 days after maximum the short period light variations were discovered with $P \sim 0.137^d$ and amplitude $A \sim 0.15$ mag. (Tempesti, IBVS No. 1052). Further observations showed slight variations of the amplitude and the period ($0.141 - 0.137^d$) Tempesti, IBVS No. 1098, Semeniuk and Kruszewski, IBVS No. 1157). Investigations showed that the alternating maxima are of different form so that the period is more likely 0.282^d (Abramenko and Prokofeva, Astron. Zh., 54, 510, Young et al., Pub. Astr. Soc. Pacific, 89, 34, Kemp et al., IAU Circ. No. 2981). Photometric and spectroscopic observations demonstrated that the light variations are connected with the continuum and not with the emission lines (Young et al., Pub. Astr. Soc. Pacific, 89, 34, Prokofeva and Abramenko, IBVS No. 1219, Ferland et al., Nature, 264, 627). It was found that the profile of the Hβ emission line shows intensity variations ($P = 0.141^d$) with a phase delay depending on the wavelength within the line (Hutchings and McCall, Ap.J., 217, 775). The origin of these light variations is not fully understood. The following hypotheses have been advanced: (a) V1500 Cyg is a close binary with the orbital period of $\sim$ 6 hours (Abramenko and Prokofeva, Astron. Zh., 54, 510, Fabian and Pringle, M.N.R.A.S., 180, 749, Marcocci et al., Astron. Astrophys., 55, 171). In this case the analysis gives the mass of the red component $M_2 \sim 0.5\ M_\odot$, the mass of the white dwarf $M_1 \sim 0.8-1.4 M_\odot$, and the orbital radius $(8.7-9.8) \times 10^{10}$ cm. (b) V1500 Cyg is a single white dwarf with an expanding envelope and with the light variations being due to either rotation or pulsation (Young et al., Pub. Astr. Soc. Pacific, 89, 34, Starrfield et al., Ap.J., 208, 23). (c) V1500 Cyg is an ellipsoidal variable (Kemp et al., Ap.J., 211, L71. It was also discovered that the intensity of the peaks of the emission lines is also variable on a time-scale of the order of minutes (Kemp et al., Ap.J., 211, L71, Ruchi and Thompson, Ap.J., 211, 184). Observations at radio wavelengths indicated that there was no strong emission from relativistic electrons during the outburst (Pynzar et al., Astr. Circ., No. 893). From an upper limit to the γ -radiation it was concluded that novae do not contribute to the galactic cosmic rays (Stepanian et al., Astron. Zh., 54, 515). The curve of growth analysis resulted in an overabundance of CNO and a normal content of Si (Boyarchuk et al., Astron. Zh., 54, 458).

The transient X-ray source A-0620-00 was identified with an eruptive star V616 Mon. From a survey of old spectrograms it was found that the star erupted also in 1917 and is probably a recurrent nova (Eachus et al., Ap.J., 203, L17). The spectrum of V616 Mon is that of a hot source with weak emission lines (IAU Circ. No. 2840).

The UBV colors suggest the presence of a red star (MO) and a hot ($\sim$ 20,000K) gas (Lutyi, Astron. Zh. Letters, 2, 402). The X-ray data give period of 7.8 d (IAU Circ. No. 2949), while the spectrophotometric data indicate P = 3.92d (Duerbeck and Walter, Astron. Astrophys., 48, 141). This period is interpreted as the orbital period. No rapid light variations have been detected (IAU Circ. No. 2854).

The curve of growth analysis of HR Del resulted in an excess of CNO both before maximum (Raikova, Astron. Zh., 54, 55) and during maximum (Antipova, Astron. Zh., 54, 68); prior to maximum this CNO excess increased with time. The spectral analysis of HR Del led to a conclusion about continuous outflow of material during the long, pre-maximum phase (Antipova, Astron. Zh., 54, 68). In addition there were ejections of clouds producing short-lived absorption components (Antipova, Astron. Zh., 55, 531). It is estimated within this model that the total amount of mass ejected was unusually large: $\sim$ 0.01M⊙ (Antipova, Astron. Zh., 54, 68). On high dispersion spectrograms of HR Del taken during the nebular stage it was found that the emission lines consist of many components which illustrates the complexity of the outburst (Gallagher and Anderson, Ap.J., 203, 625). The four strongest components are, as usually, connected with the polar condensations and polar belt. The physical conditions in these regions are different. On the early stages of the outburst the spectrum of HR Del contained also narrow emission components (of half-widths $\sim$ 30 km/s). They were observed also after maximum, their half-widths increasing with time to about 140 km/s (Raikova, Astron. Zh., 55, 540). It was found (Antipova, Astron. Zh. Letters, 4, 177) that the expansion velocity of the main envelope decreased with time. These facts can be explained by the presence - prior to the outburst - of an extensive circumstellar envelope. The mass of the main envelope obtained from the emission lines in the nebular stage was about 10^{-4}M⊙ (Anderson and Gallagher, Pub. Astr. Soc. Pacific, 89, 264).

Nova Vul 1976 (NQ Vul) was subject of extensive spectroscopic studies (Cordoni et al., Astron. Astrophys., 55, 307, Fahrenbach and Adrillat, C.r.Acad. Sci., 284, B149, Karetnikov and Medvedev, Astr. Circ., No. 935, Rafanelli and Vittone, IAU Coll. No. 42, Volf, ibid.). Short period light variations have also been noted (Cordoni et al. op. cit.). Polarization is of interstellar origin (Martin et al., Nature, 265, 314). The infrared data showed during two months after outburst the dust was formed in the envelope (IAU Circ. No. 3000).

The increasing infrared luminosity, implying the dust formation in the envelope, was observed in two fast novae: Nova Aql 1975 (Vrba et al., Ap.J. 211, 480) and Nova Sgr 1977 = HS Sgr (IAU Circ. No. 3082). From the analysis of the emission lines in the nebular stage of Nova Cep 1971 it was found that He, O, and N were overabundant (de Freitas, M.N.R.A.S., 181, 421).

An analysis of the observational data pertaining to the nova outburst (Friedjung, "Novae and related stars", 61) seems to imply that the most plausible model is that which consists of a major ejection of material near the maximum, followed by a continuous outflow. A model with a continuous outflow (thick stellar wind) due to radiation pressure was also considered (Bath et al., M.N.R.A.S., 175, 305, Bath, M.N.R.A.S., 182, 35).

The recurrent novae RS Oph, T Pyx, and V1017 Sgr were investigated to confirm the correlation between the amplitude and interval between outbursts found earlier by Kukarkin and Parenago. It turns out that this relation involves the time interval between the present and the next outburst, so that the latter can be predicted from the amplitude of the present one (Steiner, Astron. Astrophys., 62, 273).

From a statistical material including 37 novae a relation was found between the amplitude of the outburst and the absolute magnitude at minimum (Steiner, "Novae and related stars", 93). Sharov (Var. Stars, 1978) investigated the relation between the luminosity at maximum and the rate of decline and found that either the dispersion in this relation is higher than estimated earlier, or there are distant novae in galaxies located in the halo or even in the extragalactic space. Kholopov and Efremov (Var. Stars, 20, 277) found that there is no physical identity between the cycle-amplitude relations for the recurrent novae and U Gem stars.

Ford (Ap.J., 219, 595) considered the problem of the number of outbursts and concluded that all novae should be of the recurrent type with the minimum number of outbursts between 160 and 660.

14. MAGNETIC VARIABLES AND RELATED OBJECTS (K. Stepien)

The report given here does not cover the results presented at the IAU Colloquium No. 32 held in Vienna in September 1975, and published in 1976.

In the last three years the theoretical investigations concentrated mainly on the origin of stellar magnetic fields, models of rotating stars with magnetic fields, model atmospheres and origin of chemical peculiarities. Although the fossil theory has still more observational support the dynamo theory has recently gained a more firm basis by demonstrating the ability both to produce magnetic fields of the observed strength and to diffuse them to the surface of a star in a time short enough. On the other hand the models of rotating stars with perpendicular magnetic and rotation axes (Moss, M.N.R.A.S. 181, 747) showed that the anti-correlation between rotational velocity and surface magnetic field, considered as an important argument against the dynamo theory, disappears in perpendicular rotators. The most serious difficulty for the dynamo theories remains in explaining the existence of an oblique decentered dipole which best fits to observations. The attempt by Oetken (Astr. Nachr. 298, 197) to fit the magnetic field symmetric in respect to equator (being the mixture of a dipole and a quadrupole) was shaked by the observations of HD 215441 obtained by Borra and Landstreet (Ap.J. 222, 226) Also Deridder, van Rensbergen and Hensberge (preprint) showed that the Oetken's model does not give a satisfactory agreement with observations.

Thanks to a series of papers on rotating models of magnetic stars by Mestel and Moss (the references can be found in Moss op.cit.) we understand now much better the interaction of the magnetic field with rotation for different magnetic fields and finite conductivity.

A careful analysis of several magnetic stars carried out by Hensberge, van Rensbergen, Goossens and Deridder (preprint) showed that the observations do not support conclusively any hypothesis about a preferred inclination of the magnetic axis to the rotation axis.

Some authors looked for evolutionary effects in Ap stars. Earlier suggestion by Wolff (Ap.J. 202, 121) that one can observe effects of megnetic breaking operating when a star is on the main sequence has been criticized by Hartoog (Ap.J. 212, 723) who analyzed magnetic stars in four open clusters and could find no evidences for magnetic breaking. An important question in this respect is the determination of radii of peculiar stars. The radii and effective temperatures for individual Ap stars were determined by Schallis (preprint) on the base of IR photometry and model atmospheres. The results indicate that the radii of these stars are about two times larger than on the zero-age main sequence. These results are in contradiction with the results by Weiss (private communication) who, using essentially the same method, obtained radii similar to normal A type stars. Similar result was obtained by Babu and Rautela (Astr. and Sp. Sci., in print) on the basis of spectrophotometry of forty Ap, Am and A stars.

Early UV observations of Ap stars showed that they are flux-deficient in ultraviolet due to numerous and strong metal lines in this region. Line-blanketed model atmospheres are necessary to compare observations with theory and to derive meaningful physical parameters. The situation is, however, much more complicated than in case of normal stars. The latter have a uniform chemical composition and a series of standard models can directly be compared with individual stars. In case of Ap and Am stars no such standard chemical composition exists. Instead, each star has the chemical composition of its own and should be modelled individually. Using an average, most representative composition one can model only some general differences between these and normal stars. Such a series of models with one "peculiar" chemical composition was obtained by Muthsam (Astr. and Ap., in print). The results give a good agreement with observations producing the UV deficit and many other features characteristic of Ap stars. In case of the best observed magnetic star α^2 CVn Muthsam and Stepien (preprint) obtained models which show that the star has to change the effective temperature and the visible disk in course of rotation if the observed light variations are to be explained.

Model atmospheres including the magnetic forces into the equation of hydrostatic equilibrium showed (Stepien, Astr. and Ap. 70, 509) that the vertical structure of an atmosphere is very little changed in the presence of the magnetic field. The star can, however, be slightly distorted and have variations of effective temperature over its surface, contributing to the observed light variations.

Of two most widely known theories of the origin of chemical peculiarities the diffusion theory receives presently more observational support. Following Michaud et al. (Ap. J. 210, 447) who demonstrated that most of the overabundant elements in Ap stars will be pushed upwards in a relatively short time scale Alecian (Astr. and Ap. 60, 153) was able to reproduce satisfactorily the chemical composition of χ Cnc using the diffusion theory. Vauclair, Vauclair and Michaud (Ap. J. 223, 920) refined this theory by including turbulence while Vauclair, Hardorp and Peterson (preprint) were able to demonstrate that the magnetic field can play an important role in forming silicon spots on the surface of a magnetic star.

It is now generally accepted that helium-poor and helium-rich hot stars form an extension of magnetic stars into the hot domain. These stars have chemical peculiarities (even if restricted only to helium), they rotate slower than normal stars, and they have apparently a spotty structure as phtometric and spectroscopic observations show (Pedersen and Thomsen, Astr. and Ap. Suppl. 30 No. 2). Some of them have strong magnetic fields. They probably are losing matter which can be trapped in the magnetic field above the atmosphere (Landstreet and Borra, Ap.J. Letters 224, L5). But do classical magnetic stars lose matter? Some authors claim that they observe stellar winds in peculiar stars, e.g. Rakosch, Jenkner and Wood (preprint). It has also been reported in the literature that Vega - a sharp-lined normal star having the spectral type right in the middle of the interval covered by Ap stars (and believed to be very "quiet" in respect to loss of matter) - may also have a stellar wind. If Ap stars do lose matter it would seriously affect the mechanism producing chemical peculiarities.

The diffusion theory seems to have more problems with explaining Am phenomenon. There, due to the presence of two convective zones, constraints put on the diffusion theory are more severe. Hence the suggestion by Vauclair (Astr. and Ap. 55, 147) that Am phenomenon is transient in the life of a main-sequence star.

A large amount of photometric. spectrophotometric and spectroscopic data have became available in the last three years. Here we report only on photometry and spectrophotometry. Jamar, Macau-Hercot and Praderie (Astr. and Ap. 63, 155) analyzed 77 Ap stars observed with TD-1 satellite. Their conclusions are essentially similar to those earlier obtained by Leckrone. HgMn stars are least flux deficient in UV while other types of Ap stars have strong absorption features masking the true continuum. Most of these features could be identified with lines of iron peak and lighter elements. Autoionization lines may contribute in some cases. It seems that the role of rare earth elements in forming the UV pseudocontinuum of Ap stars has been overestimated in the past.

Van Dijk et al. (Astr. and Ap. 66, 187) discussed UV phtometry of 79 Ap and 26 Am stars obtained with the ANS satellite. It is demonstrated that the UV flux deficiency decreases with decreasing temperature and is absent for Am stars. A new flux of data is expected to come soon from the IUE satellite.

Many new ground-based photometric observations have became available. The complete list of these is given in Astronomy and Astrophysics Abstracts andwe mention here only the most extensive or representative studies: observations obtained by the Potsdam group, published in Astr. Nachr., vol. 297, Rakosch and Fiedler (Astr. and Ap. Suppl. 31 No. 1), Renson and Manfroid (Astr. and Ap. Suppl. in print), Hensberge et al. (Astr. and Ap. 48, 383; 54, 443), Hensberge et al. (Astr. and Ap. Suppl. 34, 67), Blanco et al. (Astr. and Ap. Suppl. 31 No. 2). They supply us with periods and amplitudes of light variations. Several newpeculiarity indices have also been proposed, like flux deficiency at 1400 A (Jamar et al., op.cit.) or those based on a particular photometric systems, e.g. vilnius system (Straizys and Zitkevicius, Astr. Zhu., 54, 987) and Geneva system (Hauck, Astr. and Ap., 69, 285). It is interesting to note in this place that Preston and Wolff (Pub. A.S.P., 90, 406) proposed to use variations of Ca II lines when looking for periods of cool Ap stars.

Although it is almost generally accepted that HgMn and Am stars do not possess strong magnetic fields and hence are not variable, their variation is reported from time to time in the literature e.g. Rakosch and Kamperman (Astr. and Ap. 55, 53) in case of α And, or Boehm-Vitense (Ap. J. 225, 514) who suggests that some Am stars may be variable on a long time scale. The problem of variability of these stars requires more attention in the future.

15. VARIABLE STAR SURVEY WORK (W. Wenzel)

A. Introduction

In the author's opinion the meaning of the word "Survey" has changed appreciably during the last decades, and to-day it seems difficult always to find the correct definition in a Report like the present. We remember the great genuine surveys in test fields of the previous decades, for instance the Harvard plan of the "Milton Fields" and the "Plan of Sonneberg Fields for the Statistics of Variable Stars of the Northern Milky way". By these two enterprises, which were expanded several times, more than 10 000 new variable stars of all types were detected in each. Tremendous stellar-statistical and astrophysical findings resulted from those work. Unfortunately, processing of the data of all the variables discovered at that time, i.e. determining of type, period, brightness etc., is not yet completed at present, because other "more modern" matters of research are taken up. This tendency is also connected with the fact that the present "surveys" are often devoted to the search for special classes of variable stars only. The Palomar-Groningen Durchmusterung for instance was mainly initiated to find a representative sample of RR Lyrae stars of the galactic halo. A third kind of photographic survey consists in searching on routine plates, for example of the sky patrol, for new variable stars, with or without giving preference to special galactic regions, or in searching on plates which originally were taken for other purposes. Finally there exists a fourth possibility, namely of performing a photoelectric survey by looking for special types of variables in certain groups of stars, for instance for β CMa variables in a sample of B stars.

B. General Surveys

As already mentioned, general surveys at present are of only small scope each, but are carried on systematically:

At the Maria Mitchell Observatory Miss Hoffleit and her collaborators regularly investigate variable stars of the Harvard lists for improvement of previous results, for finding period variations and for discovering cases of variability which are of special astrophysical importance. Results are published for instance in IBVS 958; 1207; 1349; 1431, mostly concerning stars of the Sagittarius cloud.

G. Romano at Reviso and his co-workers continued several surveys on Asiago plates. This work dealt with the fields around β Per (IBVS 999; Mem. Soc. Astr. It. 47, p. 229), M 33 (where a new Hubble-Sandage variable was discovered; IBVS 1421 = 1433; Astron. Astrophys. 67, p. 291) and M 31 (Astron. J. 82, p. 319). The number of recorded GR stars is now 292. This work will be continued in several fields in Perseus, Lyra, in high galactic latitudes, and together with L. Rosino, at M 33.

Further Asiago material including a lot of infrared plates (Kodak IN hypersensitized + RG 5) was used by L. Rosino, Padova, to search for new variables in the area around the peculiar nebula NGC 7635 Cas (Astron. Astroph. Supp. 24, p. 1) and by P. Maffei, Catania, of the field γ Cyg (IBVS 1302). Out of 62 new variables found near γ Cyg, 48, are to be classified as Miras or SR types; a previous search on blue plates of that region by G. Romano had yielded 21 such objects only, but obviously the increase of the number of variables by using infrared techniques is not quite as large as in the M 16-17 field (see Report 1973).

At Sonneberg Observatory the troublesome processing of the 488 variables discovered there by C. Hoffmeister in the field of η Ara was finished by H. Gessner (Sonneberg Veröff. 8, No. 7). The main contents of the field consists of 121 eclipsing stars, 149 RR Lyrae variables, 119 slowly variing semiregular and irregular stars and 57 Miras. The work on the fields of 20 Vir (E. Splittgerber) and α Per (H. Busch and associates) is completed, too (forthcoming no. of Sonneberg Veröff.). 5 new variables were discovered by H. Gessner in the course of a systematic search on Sonneberg Sky Patrol plates covering parts of the constellations Coma, Bootes, Corona Borealis and Hercules (Mitt. Veränd. Sterne 8, p. 65). Good progress is achieved by L. Meinunger in surveying the surroundings of M 92 on Tautenburg 52 inch Schmidt plates and on Sonneberg 40 cm astrograph plates; by this program the work described already in Reports 1973 and 1976 is continued.

By E.H. Geyer and F. Gieseking at the Observatory Hoher List of the University of Bonn, surveys in the regions of some stellar associations yielded a number of new variable stars of different kinds in the fields of μ Cep, o Per and IC 1396 (IBVS 967; 1008; 1145). During that work the old experience has been confirmed that in the course of a search amining at the finding of a special kind of variables the latter often are in the minority among the detected objects, if not very specific methods are used.

At the Bamberg Remeis Observatory the discovery, patrol and processing of variable stars of the southern sky on plates of patrol type were continued by W. Strohmeier, R. Knigge and collaborators (Bamberg Veröff. 10 to 12; IBVS 994); the number of variables discovered for finally confirmed at Bamberg (BV) has reached 1736.

C. Surveys on Special Types

Survey work on special types of variable stars cannot be quoted completely at this passage of the Report. We will rather give here an enumeration of the variety of methods and illustrate them by some characteristic examples, this brevity being necessary also to avoid overlaps.

Some of those investigations were already touched upon in the previous chapter because of their extensive importance. The work of P. Maffei and L. Rosino et al. mentioned above led for instance to a certain specialisation with respect to the discovery of Mira variables by using photographic infrared techniques. The paper in Astron. Supp. 31, p. 313 = Asiago Contr. 377 is especially important in this connection: In a Milky Way field in Sagitta surrounding the globular cluster Palomar 10, by blinking infrared plates of the 67 cm Schmidt telescope of Asiago, 123 new long-period variables have been found, the number of such stars previously known for that region having been 2!

In section B also the Bonn survey work on stellar associations was mentioned. In a special study on NGC 7000 F. Gieseking and J.D. Schumann (Astron. Astroph. Supp. 26, p. 367) continued to check the Hα emission stars announced by several previous authors. As already stated by R. Hudec et al. (for instance Mitt. Veränd. Sterne 6, p. 171) in a high percentage of those stars the presence of the $\bar{H}$ emission couldnot be confirmed. Theremaining objects, if not distant Be stars, are supposed to be T Tauri variables and related stars. The search for further emission line stars in and near NGC 7000 with the aim of objective prism plates taken with the Byurakan 40 inch Schmidt telescope has been continued by M.K. Tsvetkov and co-workers in Sofia (Astrofizika 11, p. 579; IBVS 1447). 77 new Hα stars were found by this work; of course they should be checked individually for their real membership in the T Tauri or flare type class.

At Sonneberg the novae of the halo of M 31 (see for example Report 1976) were statistically investigated by W. Wenzel and I. Meinunger (Astron. Nachr. 299, p. 239). The comparison of the number of novae in the halo of M 31 (corrected for the probability of discovery) with the density gradient of the "normal" halo stars of our Galaxy points to the conclusion that a high percentage of novae - if not all of them - belong to population II. Special surveys of M 31 and its surroundings, as initiated for instance by A.S. Sharov et al. (Astron. Tsirk. 869), and in fields of the galactic halo by means of wide-angle exposures, are urgently recommended. A test program of the latter kind was the survey of H. Gessner in Bootes and adjacent constellations mentioned above (section B); this Durchmusterung indeed yielded, among other variables, one probable nova Bootis 1962 with a maximum brightness of 10^m5 (IBVS 1428).

Occasionally the general surveys have the disadvantage of a rather coarse determination of the magnitudes of the variables found. So for example I. Meinunger by using Tautenburg 52 inch Schmidt plates had to determine a new the B magnitudes of 136 RR Lyrae variables discovered previously on Sonneberg plates in order to render possible a statistical investigation of those stars for the completion of existing similar surveys (Astron. Nachr. 298, p. 171).

A search for long period Cepheids in the direction of the Norma spiral arm (discovered radio-astronomically) was undertaken by A.L. Cabrera et al. by means of San Juan and Cerro Tololo plates (IBVS 1299). 8 new variables have been found; the type of variation however must still be investigated.

Surveys for finding new faint flare stars in star clusters and associations (Plejades, Hyades, Praesepe a.o.) are going on in a number of observatories by means of the method of multi-exposures, mostly in the U region. Without claiming to be complete we quote the observatories of Tonanzintla (G. Haro et al., Tonanzintla Bol. 2, p. 95), Byurakan, Budapest (Jankovics, Bamberg Veröff. 121, p. 120) and Heidelberg (C. Paulakos, Acta Astron. 27, p. 87).

Finally we make reference to the surveys which are performed photoelectrically in order to look for small amplitude variables of population II by R.S. McMillan et al. (Astron. Soc. Pac. Publ. 88, p. 495) at McDonald Observatory or in order to search for new β Canis Majoris stars by Baloma (South African Astr. Obs.) (RAS Mem. 84, p. 101). By the former work was intented to find short-period variables among evolved stars of low mass in the lower RR Lyrae instability strip; the result was negative. The latter work resulted in recognizing 8 new probable or certain β CMa variables out of a sample of 31 candidates.

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