(03.122.080, 04.122.091, *Ast. Sp. Sci.*, **16**, 437). The gradients dU/dB and dV/dB have been used to distinguish between different classes of variable stars (04.122.069 + 070 + 146 + 147). The Bamberg 1971 volume contains general reviews of the distribution of variables in the galaxy and the prospects for variable star observations from outside the atmosphere.

B3–B8 supergiants generally show small amplitude photometric variations and OB stars frequently do (*AA*, **20**, 437, also *AJ*, **75**, 337). Variations in the bright supergiant S Dor (LMC) have been discussed (05.122.105). *UBV* observations of Be stars over a 17 year period show 60% to be variable in V and $(B-V)$ [$\Delta V \sim 0^{\mathrm{m}}.1 - 0^{\mathrm{m}}.2$] (05.113.051). Large photometric variations in the Be star θ CrB were found in 1970 (06.122.035) and a possibly variable companion to the star was reported (06.117.014 + 015 + 016, *IB* 619). Photometry was published of Pleione and AX Mon (*IB* 698, 693, 613) and also of the P Cygni variables AG and HR Car (03.122.050, 05.122.030). P Cygni itself may belong to the Schmidt-Kaler-Isserstedt Ring 274 (*AA*, **8**, 168). The K supergiant ε Peg was reported to have brightened $\sim 1^{\mathrm{m}}.7$ for several minutes on 1972 Sept 26 (*IAU* 2450). A search for small amplitude variability amongst bright stars is being made at the Tokyo Gakugei University; ε Per (possibly eclipsing) and ν Aur have $\Delta V \sim 0^{\mathrm{m}}.1$. HD 209813 may be an intrinsically variable K star (period $25^{\mathrm{d}}.98$) in a spectroscopic binary of period $24^{\mathrm{d}}.431$ (03.119.009). During a search for δ Scuti stars a number of small amplitude variables which may be of other types were found (05.122.059). A B2V member of the open cluster NGC 7128 was found to be variable (*IB* 683). A considerable programme is underway at the Catania Observatory to search for light variations in late type stars showing variable H and K emission. First results suggest light variability in α Tau (*PASP*, **82**, 1293).

The area-scanner technique (Rakos) is being used to observe several visual double stars, one or both components of which are variables, e.g. the eclipsing systems BX And, BH Dra, AM Leo, BM Ori, the double cepheid CE Cas and the peculiar variable V389 Cyg (Geyer, Dürseck).

Extensive proper motion studies of variable stars are of great basic importance. Van Herk (Leiden) is engaged on such a programme involving 244 Miras, 12 RV Tauri's, 282 RR Lyrae's, 24 T Tauri's and 38 W UMa stars.

M. W. FEAST

President ad interim of the Commission

APPENDIX I

REPORT ON VARIABLE STARS IN GLOBULAR CLUSTERS

Mrs H. B. Sawyer Hogg

IAU Colloquium No. 21, on 'Variable Stars in Globular Clusters and in Related Systems', was held at the University of Toronto, Canada, August 29–31, 1972 with Dr. M. W. Feast as chairman of the scientific organizing committee. The papers presented will appear in a colloquium volume edited by J. D. Fernie and published by D. Reidel, which will constitute a voluminous report on this subject. (This is hereinafter referenced as *Coll.* **21**.) Probably because of all the material sent in for the colloquium, very few communications have been submitted directly to the writer for this IAU report.

1. *Catalogues*

A draft copy of the *Third Catalogue of Variable Stars in Globular Clusters* by H. Sawyer Hogg was circulated at the colloquium, for corrections and additions. The revised version will appear as *Publ. David Dunlap Obs.*, **4**, no. 6. This gives all observational references to variables in globular clusters published since the *Second Catalogue* in 1955. The material in this IAU report cannot include all references, but gives the broad outlines of work in this field since the last IAU.

Of approximately 130 clusters considered to be globular in and around our galaxy, 108 have now been examined to some degree. In these, more than 2000 variables have been found, but 13 of these clusters have no variables.

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2. *Discovery of new variables*

As might be expected after many years of searching, relatively small numbers of new variables have been found since the last IAU report. There are several aspects of significance in the new variables discovered. First, a systematic hunt for red slow variables by Menzies and Lloyd Evans (*Coll.* **21**) has yielded substantial quantities of these in the following clusters: 47 Tuc, 11; NGC 5927, 7; NGC 6171, 1; NGC 6352, 2; NGC 6356, 4; NGC 6388, 9; and NGC 6553, 9 in addition to 3 discovered earlier by Thackeray. Not all of these will prove to be cluster members. Earlier they had called attention to 2 long period variables which are members of NGC 6637. Secondly, the continued infrared researches of Terzan have yielded many variables around clusters. Terzan and Rutily (*Coll.* **21**) have found 115 new variables in a one square degree field centered on NGC 6401, of which 2 are probable members, and with Ounnas, 4 new variables in NGC 4590, with 5 field and 5 suspected. And then, Soviet work has confirmed Kholopov's earlier findings, that some announced variables in M 3 listed in recent catalogues as non-variables actually are varying. Kholopov (*Astr. Circ. Izdav. bjuro astr. Soobšč* 640, 3) has derived an RR Lyrae period for Var. 156. and Russev (*Perem Zvezdy* **18**, 171, 1971) an 80 day period for V138.

In other clusters, Menzies (*Coll.* **21**) has found 10 new variables in NGC 6723, bringing the total in that cluster to 29 and Bartolini *et al.* (*IB* 594, 662) 4 more in NGC 1261 to a total of 15. In the previously unsearched Palomar 10, Rosino has found on infrared plates a bright variable of large amplitude near the centre. In each of several other clusters one or two stars have been noted as variable (cf. *Third Catalogue*), and in some clusters there are substantial lists of suspected variables as in NGC 4833 (Menzies, *MNRAS*, **156**, 207) or unpublished, as 12 with RR Lyrae characteristics in M 14 (Wehlau and Potts). In the faint cluster Palomar 2 Rosino and Pinto (*Coll.* **21**) have searched in vain for any variables. They conclude there are probably no red variables of substantial range, but their search does not rule out the possibility of RR Lyrae stars at or below the plate limits. Kukarkin (*Coll.* **21**) stresses the difference between apparent and absolute numbers of variables in clusters relative to the total strength of the cluster, and problems of searching.

3. *Determination of periods*

An important contribution to the determination of new periods comes from Prof. G. Pinto of Padova who has used a computer to determine elements for 30 RR Lyrae variables in the very remote cluster NGC 7006. This brings the total of periods known in that cluster to 58, out of 71 variables. Kholopov is systematically determining one period after another for RR Lyrae stars in the difficult centre of M 3 and publishing them in the *Astr. Cirk. Izdav. bjuro astr. Soobšč.* Periods have been determined for the first time in NGC 5987 by Wehlau, Sawyer Hogg and Potts (*JRAS Can.* **66**, 72). The work of Menzies and Lloyd Evans, already noted, is in the nature of period determination by proving red variables, even though the specific period is not yet at hand. Kukarkin (*Astr. Cirk. Izdav. bjuro astr. Soobšč* 637) has continued his period determinations in NGC 3201, and finds that many variables are far removed from the cluster, members of it which form an extremely extended corona. Szeidl is improving periods in M 3 and Barlai in M 15, and showing Blashko effects in some stars.

4. *Period changes*

The pursuit of period changes has become very popular in recent years. The validity of the commonly used quantity, β, the rate of change per million years is strongly questioned by Kukarkin, who thinks that many period changes are in the nature of noise, and much more likely to be spasmodic than secular. He uses O-C diagrams for different epochs of well established observational series to show the behaviour of these stars. Goranskiy, Kukarkin and Samus (*Coll.* **21**) reported that in the majority of variables studied in three globular clusters, M 5, M 53, and NGC 5053, long intervals of quietness in periods were replaced by brief intervals of spontaneous changes. Of 51 studied in M 5 (Kukarkin and Kukarkina, *Perem, Zvezdy Suppl.* **1**, No. 1, 1971) 85 % show sudden leaps, 93 % of 13 studied in NGC 5024, and 75 % of 9 studied in NGC 5053. The value of the period

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leap, *I*, the durations of the quiet state of period before and after leap may be a measure of instability as earlier suggested by Parenago. Coutts and Sawyer Hogg (*Publ. David Dunlap Obs.*, **3**, 61) have shown period changes for 10 of the RR Lyrae stars in NGC 6171. Wesselink (*Coll.* **21**) is studying period changes in M 15. Belserene (*Coll.* **21**), from a study of the 43 best observed RR_{ab} variables in ω Cen finds the evidence for evolution may be present but not very strong.

An interesting new avenue in period changes has been explored by Coutts. She finds (*IAU Coll.* **15**) that a measurable effect on the period of an RR Lyrae star can result if it is a member of a binary system with certain conditions of mass and period. Variable 13 in M 3 is one such possibility. Ultimately such computations could increase our scanty knowledge of binaries in globular clusters. Coutts is also studying period changes of W Virginis stars in several of the brighter clusters. Implementing IAU recommendations that early observations be made available in print, she has published her measures of variables in M 5 on early Mount Wilson plates, taken mainly by Shapley.

5. *Color work on variables*

Observational work on variables at different wavelengths is increasing markedly. Eggen (*Ap.J.*, **172**, 639) from narrow and broad band photometry of 20 red variables in 10 clusters has determined luminosities and temperature of halo population red stars of high luminosity. Wing (*Coll.* **21**) has studied 14 red variables in 3 southern clusters on an 8-colour system of narrow band photometry in the near infrared. Feast and Glass are determining Johnson infrared magnitudes of variables and other stars in 47 Tuc and ω Cen. Dickens (*Ap.J. Suppl.*, **22**, 249) has derived color curves for 21 RR Lyrae variables in NGC 6171, and with Flinn (*MNRAS*, **158**, 99) has studied 21 RR Lyrae stars in NGC 6981, using the material to investigate the physical parameters of these stars. Menzies (*Coll.* **21**) has studied colors in NGC 6723. Curves of 45 RR Lyrae variables in *B* and *V* in Omega Centauri were studied by Geyer and Szeidl (*Astron. Astrophys.* **4**, 40, 1970) and Geyer (*Coll.* **21**) has continued the project with *U*, *B*, *V*, magnitudes and colors of 62 RR Lyrae stars in the same cluster, in which he finds 10 non-variable stars within the RR Lyrac domain. Demers has continued his *B*, *V* work on the W Virginis stars in M 13 (*Astron. J.* **76**, 445) and with A. Wehlau in M 14 (*Astron. J.* **76**, 916). Wehlau and Potts (*Coll.* **21**) have derived color curves for 25 RR_{ab} stars in this cluster from plates from three different telescopes.

6. *Determination of cluster membership*

Color work is now being used to a considerable degree to determine cluster membership of variable stars, and proving a useful accessory to the more tedious velocity and proper motion observations. Now that color magnitude diagrams are available for more than 40 clusters, the position of a variable star on the redgiant branch near the tip may be taken both as an indication of membership and of the type of variability. In fact, Eggen suspects that any star in a globular cluster with *B-V* greater than 1·6 may prove to be a red irregular variable. In NGC 6637 Lloyd Evans and Menzies (*Obs.*, **91**, 35) have used colors as an indication of variable type and membership. At the short end of the scale of periods, Jones (*Coll.* **21**) has used narrow band photometry to distinguish the membership of certain RR Lyrae stars in 47 Tuc. He finds that Var. 9 (HV 810) is a cluster member, but the other two RR Lyrae stars, Var. 12 (HV 814) and field variable HV 809 are not members. He has also studied six variables in ω Cen for the determination of various elements. Dickens, Feast and Lloyd Evans have combined infrared photometry with spectra for some red variables in ω Cen, determining membership (*MNRAS* **159**, 337).

7. *Field variables*

Kurochkin has continued his extensive search for field variables. Around M 56 he added 21 in 1970 and 30 more in 1971 (*Perem. Zvezdy* **17**, 186, 620). As noted in section 2, Terzan continues to find large numbers of variables on infrared plates toward the galactic center region, 113 field

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variables around NGC 6401. Wilkens (*La Plata Com. Ser. Circ.* **18**) continued his investigation of variables in relation to the diameters of the cluster.

8. *Interesting stars*

The eclipsing binary Var. 78 in ω Cen has drawn interest ever since Dickens and Saunders in 1965 showed it to be a cluster member and Sistero *et al.* (*IB* 316, 402) showed it to be the brightest known eclipsing binary of extreme Pop. II. Geyer (*IAU Coll.* **15**) observing the star on 15 nights in *U*, *B*, *V* finds large disturbances, up to 0·5 mag., occurring outside primary minimum and changing their position in the light curves rapidly. He concludes that the smaller, hotter component is an intrinsic variable, probably an RR_c type. The position of the star in the *c-m* diagram coincides with the brighter domain of the RR_c stars in the cluster. Near NGC 6341 Kukarkin (*Astr. Cirk. Izdav. bjuro astr. Soobšč.* 707) has found an interesting variable which, from its position in the *c-m* diagram, may prove to be of W UMa type.

9. *New techniques*

On the television equipped telescope of the Crimean Astrophysical Observatory, Mironov (*Astr. Cirk. Izdav. bjuro astr. Soobšč.* 637) has obtained the light curves of five RR Lyrae variables in M 15. The time of rolling of the film on the television receiver ranged from 1·28 to 2·56 sec. On each shot, from 50 to 100 photo sequences were integrated, so that the exposure was 1–2 min.

10. *Period luminosity relationship*

Determinations of this important relationship continue to be produced both observationally and theoretically. From color studies of Cepheids Demers and Wehlau (*Astron. J.* **76**, 916) have derived a period luminosity relation from 17 variables in four clusters, as follows: $(M_V) = -0.016 - 1.65 \log P$. They note that no period color relation is evident for all stars, but the variables in M 14 and ω Cen do follow such a relationship. Kukarkin and Rastorguev (*Coll.* **21**) have reduced to the B, *V* system magnitudes for 27 Cepheids in 10 globular clusters. They find that the relation may be represented by two straight lines, that 4 Cepheids may be in a different evolutionary stage from the others, and that the shape of the light curve as well as the period length should be considered.

For the RR Lyrae stars in several globular clusters, Breger and Bregman have found that RR_{ab} stars in different clusters do obey the same period-luminosity-color relation. $M_V = -2.89 \log P + 3{\cdot}28\,(B\text{-}V) = \text{const}$. These periods have been analyzed by a new statistical method. This relation is almost identical to the theoretical relation given by van Albada and Baker (*Ap.J.*, **169**, 311).

11. *Theoretical*

Much theoretical work centers around the following aspects of variables in clusters:

(a) Explanation of numbers and types of variables, and of Oosterhoff groups I and II, in terms of metallicity and other cluster parameters. Castellani, Giannone and Renzini (*Coll.* **21**) show that globular clusters do not form a unique sequence. Clusters with the same metal content may have different horizontal branch morphologies, and an age difference may explain mean period differences. Van Albada and Baker (*Ap. J.*, **169**, 311 and *Coll.* **21**) have considered abundances of Y and Z, and find a dichotomy in the "transition period" between RR_{ab} and RR_c which reflects a difference in effective temperature at this point. This may indicate different predominant directions of evolution along the horizontal branch.

(b) Interpretation of period changes. Sweigert and Demarque (*Coll.* **21**) show that a growth in the convective core mass near the end of the horizontal branch phase will lead to a rapid blueward movement of models in the HR diagram. This movement gives rise to rates of period changes greater than those caused by normal evolutionary changes on a nuclear time scale.

(c) Evolutionary status of Pop. II Cepheids. Schwarzschild and Harm (*Ap.J.*, **160**, 341) calculated that type II Cepheids are in loops of final evolution off the asymptotic branch. This is supported by findings of Wallerstein (*Ap.J.* **160**, 345) from observations of Cepheids in many clusters, that these occur only in clusters with a strongly blue horizontal branch, but Kukarkin and Voroshilov (*Astr. Cirk. Izdav. bjuro astr. Soobšč* 617) disagree with some of these ideas from the standpoint of masses. Mengel (*Coll.* **21**) also supports the earlier work for periods greater than 8 days, but finds a smaller number of loops. Kraft (*Dudley Obs. Rept.* **4**, 69) suggested that Cepheids with shorter periods are evolving off the horizontal branch, also confirmed by Mengel.

12. *Summaries*

Excellent review papers in this field presented at the *IAU Colloquium* **21** deserve special mention. M. W. Feast presented 'Observational Aspects of Slow Variables in Globular Clusters', L. Rosino 'Observational Aspects of RR Lyrae Variables in Globular Clusters', and P. Demarque 'Variable Stars and Evolution in Globular Clusters'.

13. *Variables in clusters of external galaxies*

As is to be expected from the great observational difficulties involved, the study of these variables proceeds slowly, and so far concerns only those of Magellanic Cloud clusters. The cluster NGC 1466, a red globular, lies between the two clouds at the distance of the Larger. Wesselink has found this to be very rich in variables (*MNRAS*, **152**, 159). For the 43 RR Lyrae stars he has published periods and light curves for 6. Norris (*Coll.* **21**) has brought the number of periods to a total of 10, of which 9 are RR_{ab} and 1 RR_c. He notes that the mean period of the RR_{ab}'s is 0·533, and that so far no clusters with longer ab type periods have been found in the Magellanic Clouds, suggesting that this system is not as evolved as the galaxy. The cluster NGC 1835, a compact cluster close to the LMC bar, has been found by Graham and Ruiz (*Coll.* **21**) to be rich in variables. There are 21 definite, out of 49 suspected. Periods have been determined for 10, 9 of which are RR_{ab} and 1 RR_c. The others are a long period, a possible Cepheid, and some more RR_c. Near the cluster NGC 1783 in which Gascoigne noted 3 variables in 1962, Graham (*PAS Pacific*, **82**, 918) has found an eclipsing variable 2′ from the center, with period around 1 day or 2 days. Despite a careful search, he found no RR Lyrae variables on 60-inch Cerro Tololo plates. Gaposhkin (Payne Gaposchkin, *Smithsonian Contrib. Astrophys.* **13**) has found two faint RR Lyrae stars, HV 13015 and 13016, in the faint cluster, HS 83 of the Large Cloud, and considers them members of the cluster. Demers (*Coll.* **21**) with the University of Toronto 24-inch on Las Campanas has studied the colors of 6 Cepheids in 3 red globular clusters of the Large Cloud. These are the variables with periods over a day in and near NGC 1751, 1953 and 2121. Variables in these distant clusters constitute one of today's challenges to be met with the new equipment in the southern hemisphere.

APPENDIX II

REPORT OF THE WORKING GROUP ON SUPERNOVAE

By the end of 1969 the supernovae discovered since 1885 and included in Zwicky's master list had reached the number 260. The rate of discovery at 12 participating observatories, in 1969 had reached about 15 supernovae per year. Since then, the same rate has been maintained as far as active supernovae are concerned, about 40 having been discovered between January 1, 1970 and May 13, 1972. In addition to these, however, 37 past supernovae were found on the original Palomar Sky Survey Plates and later comparison plates through a systematic search initiated by Zwicky a few years ago. The Master List, by May 13, 1972, consequently contained 336 bona fide supernovae. After further checks two more objects may have to be added to this list, that is a fifth supernova in NGC 6946, discovered by Rosino and one old one announced by Lovas as having been found on