37. COMMISSION DES AMAS STELLAIRES ET DES ASSOCIATIONS

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INTRODUCTION

The data contained in this report have, as in preceding years, been taken from two sources: (1) Information received from astronomers active in the field of Commission 37 in response to a circular letter mailed 1 July 1966. (2) A search of the literature. The report is divided into three main sections, dealing with associations, open clusters, and globular clusters. The section on associations has been prepared by Dr J. Ruprecht, and that on globular clusters by Professor L. Rosino. Both sections are included here as received. As in previous reports, the data for the sections on associations and open star clusters have been condensed in so far as possible into two tables. Clusters and associations belonging to the Magellanic clouds or other extragalactic systems are omitted from this report since they are reported in Commission 28.

CATALOGS

G. Alter, H. Sawyer Hogg and J. Ruprecht (**1, 2, 3**) have published three additional supplements (Numbers 7–9) to the *Catalog of Star Clusters and Associations*. At the XIIth General Assembly, it was decided by Commission 37 that the publication of a new edition of this catalog should be undertaken. I am happy to announce that negotiations for the publication of the work have now been completed. The authors of the new edition will be G. Alter, B. Balázs, J. Ruprecht, and V. Vanýsek and the Catalog will be published by the Publishing House of the Hungarian Academy of Sciences. It is expected that the manuscript will be sent to press in the summer or fall of 1967. Owing to the appearance of the new edition of the Catalog, no additional Supplements to the first edition will be issued.

The most useful *Atlas of Open Clusters South of* $-45°$ *Declination*, mentioned in the last report, has now been published by A. R. Hogg and V. O. Hunt. The *Atlas* consists of photographic prints of the fields of 133 clusters from plates taken with the Mt Stromlo 74-inch reflector. The limiting magnitude is about $m_{pg} = 16$ to 17, and the print scale is 15″/mm. In addition, a *Catalog of Open Clusters South of* $-45°$ *Declination* has been published by A. R. Hogg (**4**) giving the coordinates, apparent diameters, total number of stars, and estimated number of member stars for each of the clusters in the *Atlas*.

After many years in preparation, Trumpler's extensive spectroscopic and photometric observations of open clusters have now been prepared for publication by H. F. Weaver. According to Weaver; 'the manuscript, including explanatory text, is now complete and in form to go to the printer, probably soon after 1 January 1967.'

Ruprecht (**5**) has classified all of the known open star clusters on the Trumpler system.

Sher (6) has published descriptions of all clusters (40 in number) which have been listed as occurring near eta Carina.

Barkhatova and Syrovoi have completed the compilation of the atlas, mentioned in the preceding report, of color-magnitude diagrams of clusters and associations. This atlas has been compiled from observations published up to and including 1962.

ASSOCIATIONS

(Prepared by J. Ruprecht)

Recent results and work in progress are summarized in Table 1 which is self-explanatory.

A. H. Batten (Dominion Astrophysical Observatory, Victoria) has continued observations on Cyg OB 3 (NGC 6871), Cyg OB 1 (NGC 6913) and Cyg OB 4. This work is being done in collaboration with C. H. Costain, of the Dominion Radio Astrophysical Observatory, who

Table 1. Associations

Name	Observer and reference (see end of table)	Photometry, method and limiting magnitude			Other data obtained, ren
Vul OB 4	Bartaya, Kharadze (1)				list of 1240 stars
Cyg OB 1	Batten				s.t., r.v.
Cyg OB 2	Crawford	*uvby*, Hβ			
Cyg OB 3	Batten				s.t., r.v. material collect
	de Vegt				expansion age = 1·6 ×
Cyg OB 4	Batten				s.t., r.v. indicate not p group
Cyg OB 7	Walker, G. A. H.				s.t., equivalent widths
Cep OB 3	de Vegt (2)				expansion age = 1·6 ×
Cas OB 2	Reddish, Lawrence, Pratt (3)	*UBV*	pg+pe	21	CE, structure, rotation
Cas OB 4	Walker (4)				s.t., r.v., equivalent wic Hγ
	MacConnell (5)	*UBV*	pg	13·0	44 probable members; s
Cas III, Cas OB 4, Cas OB 7	Bartaya, Kharadze (6)				list of 376 O–B8 stars
Mon I	Schmidt-Kaler	*uvby*, Hβ	pe		43 stars
Ori OB 1	Lodén, Morgan (7)	*UBV*			35 stars in two clusterin
	Crawford (8)	Hβ	pe	9	
Pup OB 1	Lodén (9)	*UBV*			s.t., total/selective absor
	Lodén (10)	*UBV*			MK classification, mor one assoc.?
Cen OB 2	Thackeray, Wesselink (11)	*UBV*		15	spectroscopy of bright
Ara OB 1	Graham (12)	*VBLUW*	pe	11	r.v. and Walraven
	Brück, Smyth (13)	*UBR*	pg+pe	15·7	22 OB stars
	Brück, Smyth	*UBV*	pg	17	plates taken
Sco OB 1	Bok, Bok, Graham (14)				photometry for 9 stars
	Braes, Hovenier (15)				possible supernova ren
	Andrews	*UBV*	pg	18	s.t. of selected stars to
			pe	17	
Sco OB 2	Thackeray (16)				r.v. (confirmed conce communal motion)
	Graham (17)	Hβ	pe	5	33 stars in southern se
Sco OB 4	Lyngå (18, 19)	*UBV*	pe	11·9	part in Norma

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Abbreviations and References to Table 1

abs.	= absorption	pg	= photographic
ass.	= association	r.v.	= radial velocities
CE	= color excess	s.t.	= spectral types
pe	= photoelectric		

1. *Bull. Abastumani astrophys. Obs.*, no. 34, 109.
2. 1966, *Z. Astrophys.*, **64**, 268.
3. 1965, *R. Obs. Bull.*, **5**, no. 8, 111.
4. 1965, *Astrophys. J.*, **141**, 660.
5. *Astr. J.*, in press.
6. *Bull. Abastumani astrophys. Obs.*, no. 34, 105.
7. 1966, *Vistas in Astronomy*, **8**, 83.
8. *Astr. J.*, in press.
9. 1966, *Ark. Astr.*, **4**, 65.
10. 1966, *Astrophys. J.*, **141**, 668.
11. 1965, *Mon. Not. R. astr. Soc.*, **131**, 121.
12. 1966, *Bull. astr. Inst. Netherl.*, **18**, 372.
13. 1966, *R. Obs. Bull.*, **5**, no. 10, 195.
14. 1966, *Mon. Not. R. astr. Soc.*, **131**, 247
15. 1966, *Bull. astr. Inst. Netherl.*, **18**, 294.
16. 1966, *Mem. Soc. astr. Ital.*, **70**, 33, and *IAU Symposium No.* 30.
17. *Mon. Not. R. astr. Soc.*, in press.
18. 1964, *Acta Univ. Lund. II*, no. 11 = *Lund Obs. Medd. II*, no. 139.
19. 1964, *Acta Univ. Lund. II*, no 13 = *Lund Obs. Medd. II*, no. 140.

plans 21 cm observations of these regions. Neither the radial velocities, nor the spectroscopic absolute magnitudes give any reason for supposing that the four stars supposed to form Cyg OB 4 are in any way related. The observations on Cyg OB 3 are not yet reduced.

Special consideration has been devoted to the association Cyg OB 2 at the Royal Observatory Edinburgh. L. C. Lawrence and V. C. Reddish (**7**) have shown that photographic *UBV* photometry of this association and the nearby cluster NGC 6910 present systematic differences from the published photoelectric magnitudes used for calibration purposes. No source of error could be found in the photographic photometry large enough to account for the discrepancies. The coming into operation of the twin 16-inch (41 cm) photoelectric telescope at Edinburgh enabled the photoelectric magnitudes to be measured; the results showed that the discrepancies had been due to errors in the published photoelectric magnitudes.

The dependence of interstellar reddening on luminosity among O and B stars has been investigated by V. C. Reddish (**8**). The increase of interstellar reddening of stars with increasing stellar luminosity has been found in all clusters and associations containing stars brighter than $M_v = -9$ (ages $< 10^5$ yr). The effect is found most strongly in Cygnus OB 2 association. It has been concluded that very young early-type stars are surrounded by obscuring clouds having diameter $\leqslant 1$ pc and masses probably around 30 $\mathfrak{M}_\odot$.

Research on the association Cyg OB 2 has been continued by V. C. Reddish, L. C. Lawrence and N. M. Pratt (**9**). Star counts and *UBV* photometry show that the association contains 3000 stars brighter than $m_r = 20$, 900 brighter than $m_{pg} = 21$ and 400 brighter than $B = 16{\cdot}5$, of which at least 300 are OB stars. The distance is 2·1 kpc, and the shape is elliptical, 29 pc by 17 pc. The total mass is between $1{\cdot}6 \times 10^4$ and $6{\cdot}3 \times 10^4$ $\mathfrak{M}_\odot$, with 60% of the mass in obscuring clouds surrounding the stars. The association may be rotating about an axis in the Galactic plane with an equatorial speed of 2 to 4 km s^{-1}.

D. MacConnell (University of Michigan) found the distance (825 pc) and probable age

(6×10^5 to 2×10^6 yr) of the association Cep OB 4. Some of its members have been found probably to belong to the T Tauri class. One faint flare star has been discovered.

R. Ampel (**10**) has examined the distribution of 275 OB stars within the associations Cas III, Cas OB 4, Cas OB 5, using objective prism spectra, and photographic and photovisual photometry calibrated on photoelectric standards.

An investigation of P. Maffei (Rome) on the variables of the Orion nebula with plates obtained at the Hamburg Observatory in the years 1920–21 is very far advanced. The main purpose of this work, which is being done in collaboration with A. Blagikh, is to compare the behavior of the variables of this association at different times.

From Kitt Peak D. L. Crawford reports that the Hβ-photometry, combined with the *UBV* photometry of Hardie *et al.* for stars in the Orion Belt region, indicate that these stars are approximately all the same age but not at the same distance.

A. D. Thackeray and A. J. Wesselink (**11**) derived distance 2·0 kpc of the association Cen OB 2 (IC 2944). The O-type stars show no large Trumpler red shift. There is evidence of expanding gas around the association.

An extensive investigation of the proper motions and photometric properties of the association Sco OB 1 and the associated cluster NGC 6231 by L. Braes is now approaching its completion and will soon be published in the *Bull. astr. Inst. Netherlands*. It is based on early and modern Cape Observatory Photographs. It results in separation of association and field stars and in a determination of the systematic motion of different parts of the association.

C. Roslund (**12**) reports that the possible association Sco OB 4, found by Pik-Sin The (**13**), extends outside the field surveyed by The, at least to the south. The areal distribution of the O and early B type stars indicates that the nucleus of the association is to be sought in the nebular region of NGC 6334. Physical relationship between the young stars and the nebulosity was demonstrated.

Research by T. S. van Albada and A. Blaauw on the binary properties in the nearest O association reported earlier, has been continued. The observations of spectroscopic binaries for determination of periods and amplitudes have been extended to the Scorpio-Centaurus cluster. Van Albada is now also engaged in theoretical work on the dynamics of small young groups in which binary formation may occur as a consequence of multiple encounters.

G. A. H. Walker, assisted by S. M. Hodge, has attempted to extend the investigation of the possible differences between the width of Hγ-line-spectral type relations for different clusters. They have measured Hγ equivalent widths and estimated spectral types, both from low dispersion spectra in the associations Cas OB 6 (around IC 1805), Aur OB 2 (NGC 1893), Ser OB 1 (NGC 6611), Vul OB 1 (NGC 6823), Cyg OB 2, Cyg OB 1 (NGC 6910) and the components of HD 5005.

L. L. E. Braes and J. W. Hovenier (**14**) have concluded that there may be a close relationship between observed X-ray sources and supernova remnants in OB associations nearer than 2 kpc

A review of properties of the O associations within 1000 pc from the Sun has been published by A. Blaauw (**15**). Space distribution, stellar content, and internal motions of the associations are discussed. Special attention is given to the occurrence of subgroups of different ages and their properties.

An investigation of the internal motions of several of the nearest O associations, based on the most recently determined meridian circle positions is now being carried out by A. Blaauw in collaboration with several associates.

E. L. Chentson (Sverdlovsk, U.S.S.R.) conducted spectrophotometric studies of super-giant stars ranging from class B8 to K2 which are possible members of the stellar associations Ori OB 1, Perseus OB 1 and the cluster NGC 457.

Byurakan Astrophysical Observatory has made some progress in the study of stellar associations (L. V. Mirzoyan, E. S. Kazaryan). To check the previously obtained 'hyperbolic' law of distribution of the OB stars around the nucleus of a synthetic association, a distribution of 98 probable OB star members of the Per OB 1 association around their double nucleus (h and χ Per) was deduced (**16**). The dependence of the age of OB stars on distance from the nuclei has been studied and the period of the semiage of these stars (5×10^6 to 2×10^7 yr) has been estimated. The observed distribution of the OB stars around the nuclei is satisfactorily represented by exponential laws of aging of stars.

U. Haug (**17**) in collaboration with J. Pfleiderer and J. Dachs has investigated the distribution of 105 early spectral type stars in Norma ($l = 332°$, $b = -2°$) and 38 similar stars in Circinus near $l = 321°$, $b = -1{\cdot}5°$. According to a preliminary statistical discussion, some highly reddened stars, situated near the Hα-emission regions Mt Stromlo nos. 101, 102 and 106, may have high luminosities and distances of about 4 kpc.

J. A. Graham (**18**) studied three groups of OB type stars which appear to be physically associated with Wolf-Rayet type stars. Using distances based on Hβ and U, B, V, photometry for the OB stars, he found a mean absolute magnitude of $-6{\cdot}4$ for 7 Wolf-Rayet stars of the type found in young associations.

L. O. Lodén has paid particular attention during the examination of the material from the Stockholm Observatory Milky Way Survey to stellar associations. A special program is devoted to the detection of associations of intermediate type stars and very open clusters, which can only be detected by means of spectroscopic material.

Mrs H. Antalová (Skalnaté Pleso, Czechoslovakia) has investigated the distribution of the O–B2 stars in the direction of the galactic center by means of photographic *UBV*-photometry. Two groups seem to be shown in the distances of 1·2 to 1·4 kpc and 3·0 kpc respectively.

The survey of faint Hα-emission stars in southern Milky Way fields containing bright and/or dark nebulosities is being continued by Pik-Sin The and the results for the following regions have already been published: Ophiuchus (**19, 20**), Scorpius (**21**). These groups of Hα-emission stars, which are seen projected against bright and/or dark nebulosities, are probably members of T-associations.

P. Maffei (**22**) has discovered 13 variable stars, most of them of RW Aur type, on 204 plates (blue and infrared) obtained at the Observatories of Asiago and Loiano, in the field of NGC 2169. This field (where some emission stars were already known) contains therefore a T association which, perhaps, is distinct from Mon T_1. Some other new T Tau variables have been found in the fields of NGC 1579, IC 405 and HGC 6611 (**23, 24**).

OPEN CLUSTERS

So far as possible, information relating to recent or current observations of open clusters has been collected in Table 2; the discussion in the text is limited to those investigations that are not adequately described by the line-entries in the table. Omitted from the table are: clusters 'to be observed' for which no material has so far been obtained, radio observations, observations of nebulae associated with clusters, and general discussion papers or catalogs of clusters. While an attempt has been made to make the list of published investigations reasonably complete, no effort has been made to include here *every* published paper, since we have available the *Catalog of Clusters* and its Supplements. In general, all references to papers published in 1964, 1965 and 1966 and received by the closing date of the literature search (15 September 1966) are included. Some references to investigations published in 1963 are included except for those already published in the last report, and a few 1962 publications not quoted in the last report are also included, although no effort was made to obtain completeness for this year. References not available in the Lick Observatory library have been omitted except in those cases where they were referred to by astronomers who responded to the circular letter. It is sometimes difficult to determine, in the case of clusters which are the nuclei of associations, whether the observations should more properly be listed in Table 1 or Table 2. Since the two tables were prepared independently, some duplication of material will be found.

Table 2. Open Clusters

NGC	Observer and references (see end of table)	Photometry, method and limiting magnitude			Other data obtained, rem
188	Greenstein, Keenan (1)			14·7	s.t., r.v. red giants
	Hoffmeister (2)				4 var. stars
	Efremov, *et al.* (3)				var. stars = W UMa type
	Barkhatova, Zinina (4)	*UBV*		17	$c-m$, $L(M)$, structure, v stars
	Sharov (5)	*B*		18	structure
	Sharov (6)	*BV*	pg	15	stars in region
	Golay	$UBB_1B_2VV_1G$	pe	10	obs. in prog.
225	Dolidze, Ponomareva (7)				45 emHα stars in region
457	Lavdovsky (8)				p.m., mem., c.l. mot.
	Morris				s.t., r.v., EW Hγ
	de Vegt				abs. p.m., sp. v.
	Grigoryan				pol.
559	Lindoff	*UBV*	pg + pe	14·5	plates taken
581	McCuskey, Houk (9)	*UBV*	pg	12·5	
	Oja (10)			15·5	p.m.
	Oja	*UBR*			2000 stars w/in 1 sq. de 1000 stars
	Lavdovsky (8)				p.m., mem., cl. mot.
Tr 1	McCuskey, Houk (9)	*UBV*	pg	12·5	
	Oja (10)			15·5	p.m.
	Lavdovsky (8)				p.m., mem., cl. mot.
654	McCuskey, Houk (9)	*UBV*	pg	12·5	
659	McCuskey, Houk (9)	*UBV*	pg	12·5	
663	McCuskey, Houk (9)	*UBV*	pg	12·5	
	Morris				s.t., r.v., EW Hγ
752	Kholopov, Artyukhina (11)	*B*		16	$L(M)$
	Barkhatova (12)				cl. rot., age
	Gunn, Kraft (13)				chem. comp. 2 stars
	Wallerstein, Conti (14)				chem. comp. 1 star
	Wallerstein, *et al.* (15)				r.v. 1 star
	Cannon	*BV*			p.m. 238 stars
	McNamara	*uvby*, Hβ	pe		
	Golay	$UBB_1B_2VV_1G$	pe	10	
Stock 2	Krzeminski, Serkowski	*UBV*		13	pol.
869 = *h* Per	Pratt (16)	*UBV*	pg	12·5	pol. in *B*, *V*
h + χ Per	Serkowski (17)		pe	11·7	pol. in *B*, *V*
	Wildey (18)	*UBV*	pg + pe	18	$c-m$, age
	Schild (19)			12	s.t., HR diag.
	Crawford	*uvby*, Hβ			obs. in prog.
	Golay	$UBB_1B_2VV_1G$	pe	10	obs. in prog.

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Observer and references (see end of table)	Photometry, method and limiting magnitude			Other data obtained, remarks
Vasilevskis, *et al.* (**20**)			14·2	p.m., mem.
Underhill				r.v.
Golay	$UBB_1B_2VV_1G$	pe	10	
de Vegt				abs. p.m., sp.v.
Walker, G. A. H.				s.t., EW Hγ
Larsson-Leander	BV	pg+pe	16	s.t.
Mathews (**21**)	V	pg	13	
de Vegt				p.m. plates taken
Golay	$UBB_1B_2VV_1G$	pe	10	obs. in prog.
Guthrie (**22**)				Hγ line int.
Crawford	*uvby* Hβ			obs. in prog.
Heard, Petrie				s.t., r.v. 77 stars
McCarthy, Treanor (**23**)			17·3	s.t. M stars
Guthrie, Nandy (**24**)				tot./sel. absorption
Abt, *et al.* (**25**)				r.v. 46 stars for s. bin.
Crawford	*uvby*, Hβ	pe		material collected
Golay (**26**)	$UBB_1B_2VV_1G$	pe	10	
de Vegt				abs. p.m., sp. v.
Barkhatova, Zakharova	UBV		16·5	$c-m$, $L(M)$, structure
Mathews (**21**)	V	pg	13	
Barkhatova, Kuzmina	BV		16·5	$c-m$, $L(M)$, structure
Larsson-Leander	BV	pg+pe	16	s.t.
Barkhatova, Kuzmina, Shashkina	UBV		16·5	$c-m$, $L(M)$, structure
Golay	$UBB_1B_2VV_1G$	pe	10	
Helfer, Wallerstein (**27**)				chem. comp. 4 giants
Conti, *et al.* (**28**)				Li/Ca 23 stars
Conti (**29**)				chem. comp. metallic line stars
Wallerstein, Conti (**14**)				chem. comp. 1 star
Wallerstein, *et al.* (**15**)				r.v. 1 star
Kraft (**30, 31**)				rot., effect on colors
Crawford (**32**)	*ubvy*, Hβ	pe		132 stars
Woolley, Harding (**33**)				r.v. 9 stars
Morgan, Hiltner (**34**)				s.t. 79 stars
Luyten (**35, 36**)			21	p.m.
Giclas, *et al.* (**37**)			17	p.m.
Wayman, *et al.* (**38**)				p.m. 231 stars
Murray, *et al.* (**39**)			15·5	p.m. 69 stars
Golay (**40**)	$UBB_1B_2VV_1G$	pe	10	
Golay	$UBB_1B_2VV_1G$	pe	10	
Golay	$UBB_1B_2VV_1G$	pe	10	
Börngen (**41**)	U	pg	14·5	
Fang	UGR	pg	16	
Grigoryan				pol.
Bakos, Rymer (**42**)				var. star $P=75$ min.
Serkowski (**17**)		pe	11·7	pol. in B, V
Walker, G. A. H.				s.t., EW Hγ
Mathews (**21**)	V	pg	13	
Johnson (**43**)				s.t., r.v. 45 stars
Walker, M. F.	UBV	pe	14	
Walker, M. F. (**44, 45, 46**)			16·5	s.t., r.v. UV excess stars
Svolopoulos (**47**)	UGR	pg	19	

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NGC	Observer and references (see end of table)	Photometry, method and limiting magnitude			Other data obtained, re
2099	West (48)	*UBV*		17·7	
	Upgren (49)				p.m. 600 stars
	Jeffries (50)				p.m. 242 stars
	Artyukhina, Kholopov (51)			17·0	structure
King 8	Svolopoulos (47)	*UGR*	pg	18	
2129	Wick (52)	*UGR*	pg	17	$L(M)$
2168	Becker	*UGR*			
	Douglass	*BV*	pg		s.t., r.v., $L(M)$
	Golay	$UBB_1B_2VV_1G$	pe	10	
	Morris				s.t., r.v., EW Hγ
2169	de Vegt				p.m. plates taken
	Golay	$UBB_1B_2VV_1G$	pe	10	
2244	de Vegt				p.m. plates taken
	Golay	$UBB_1B_2VV_1G$	pe	10	
	Morgan, *et al.* (53)				s.t. OB stars
	Walker, M. F.	*UBV*	pg + pe	16	material collected
	Serkowski (17)		pe	11·7	pol. in *B*, *V*
An (van den Bergh)	Preston (54)			15	s.r. 19 stars
2264	Bretz (55)				em. Hα stars
	Golay	$UBB_1B_2VV_1G$	pe	10	
	Graham	Hβ	pe	9	9 stars
	McNamara	*uvby*, Hβ			mem. of A–F stars
	Morgan, *et al.* (53)				s.t. OB stars
	Vasilevskis, *et al.* (56)			16	p.m. 245 stars. mem.
	Walker, M. F. (44, 45, 46)			16·5	s.t., r.v. UV excess stars
2281	Alcaino (57)	*UBV*	pg + pe		121 stars
	Wallerstein, Conti (14)				chem. comp. 2 stars
	Wallerstein, *et al.* (15)				r.v. 2 stars
Cr 121	Feinstein	*UBV*	pe	9·5	also bright stars in vicin
2401	Basel Observatory	*UGR*	pg	18	
2412	Basel Observatory	*UGR*	pg	18	
2421	MacConnell				3 em. Hα stars
2422	Serkowski (17)		pe	11·6	pol. in *B*, *V*
2420	West (48)	*UBV*		19	
Mel 71	Basel Observatory	*UGR*	pg	18	
Haffner 12	Basel Observatory	*UGR*	pg	18	
2437	Riddle	*UBV*	pg + pe	16·5	s.t.
2451	Williams	*UBV*		12	82 stars. 'Cl.' = nucleus 2° dia.
	Feinstein (58)	*UBV*	pe	9·5	s.t. 8 stars
2467	Lodén (59)	*UBV*	pe	13·5	not a physical cl.
2533	Lindoff	*UBV*	pg + pe	14·5	material collected
2548	Wallerstein, Conti (14)				chem. comp. 1 star
	Wallerstein, *et al.* (15)				r.v. 1 star
2567	Lindoff	*UBV*	pg + pe	14·5	material collected
2571	Lindoff	*UBV*	pg + pe	14·5	material collected
Praesepe	Wallerstein, Conti (14)				chem. comp. 2 stars
	Crawford	*uvby*, Hβ			material collected
	Golay (40)	$UBB_1B_2VV_1G$	pe	10	
IC 2391	Buscombe (60)				s.t., r.v., abs. mag., EW Hδ
	Graham	Hβ	pe	7	11 stars

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Observer and references (see end of table)	Photometry, method and limiting magnitude			Other data obtained, remarks
Greenstein, Keenan (**1**)				s.t.
Eggen, Sandage (**61**)	*UBV*	pe	16·6	$c-m$, line blanketing
Pesch				s.t., r.v. 8 stars
Golay	$UBB_1B_2VV_1G$	pe	10	obs. in prog.
Tammann	*UGR*		15	
Bakos (**62**)				var. star not mem.
Kholopov (**63**)	*BV*	pg	13	all stars w/in $r=16'$
Kholopov, Artyukhina (**64**)	*B*	pg	17	$L(M)$
Murray, *et al.* (**65**)			16·5	p.m. in $27' \times 27'$ area
Murray				p.m. in $1° \times 1°$ area
Lindoff	*UBV*	pg	15	material collected
Evans, Lloyd	*UBV*	pg + pe	15	r.v. 2 stars. Obs. in prog.
Andrews	*UBV*	pg + pe	17	pe to 16. Obs. in prog.
Feinstein	*UBV*	pe	11	connected to Tr 16
Feinstein (**66**)	*UBVRI*	pe	11	extension of work in (**66**)
Feinstein	*UBV*	pe	11	connected to Tr 16
Sher (**67**)	*UBV*	pg + pe	15	real cl.?
Sher (**67**)	*UBV*	pg + pe	15	real cl.?
Feinstein (**68**)	*UBV*	pe	10	around He star HD 96446
Schmidt, Santanilla (**69**)	*UBV*	pg	13	$c-m$ 50 stars
Schmidt, Santanilla (**69**)	*UBV*	pg	13	$c-m$ 84 stars
Graham	Hβ	pe	10	6 stars
Schmidt, Santanilla (**69**)	*UBV*	pg	13	$c-m$ 36 stars
Sher (**67**)	*UBV*	pg + pe	15	
Sher (**67**)	*UBV*	pg + pe	15	
Sher (**67**)	*UBV*	pg + pe	15	
Thackeray, Wesselink (**70**)	*UBV*	pe	15	61 stars, s.t., r.v., 24 stars
Engver (**71**)	*UBV*	pg + pe	14·5	
Wesselink	*BV*			300 stars
Crawford (**72**)	*uvby*, Hβ	pe		37 stars
Golay (**26**)	$UBB_1B_2VV_1G$	pe	10	
Mendoza (**73**)	*UBVRI*	pe	11	s.t. 54 stars
Upgren, Rubin (**74**)	*UBV*	pe	10	s.t., r.v. 7 stars
Anderson (**75**)				p.m. cl. not real
Wesselink	*BV*			obs. in prog.
Graham	Hβ	pe	8	5 stars
Rahim (**76**)	*UBV*	pg + pe	15·6	
Lyngå (**77**)	*UBV*	pg + pe	13·1	
Lyngå (**77**)	*UBV*	pg + pe	12·1	
Symth	*UBR*	pg + pe	15	plates taken
Smyth	*UBR*	pg + pe	15	plates taken
Lyngå (**77**)	*UBV*	pg	14·6	
Lyngå (**77**)	*UBV*	pg	15·2	
Lindoff	*UBV*	pg	16	
Lyngå (**77**)	*UBV*	pg + pe	16·5	
Engver (**71**)	*UBV*	pg + pe	14	
Wesselink	*BV*			background stars
Landolt (**78**)	*BV*	pg	14·3	c–m, $L(M)$
Graham	Hβ	pe	10	18 stars
The (**79**)	*BV*	pg + pe	14	
Smyth	*UBR*	pg + pe	15	plates taken
Brück, Smyth (**80**)	*UBR*	pg + pe	15·7	940 stars

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NGC	Observer and references (see end of table)	Photometry, method and limiting magnitude			Other data obtained,
Wolf 630 mov. cl.	Eggen (**81**)	*UBV*	pe		mem.
6231	Feinstein	*UBVRI*	pe	10	material collected
	Andrews	*UBV*	pg+pe	17	s.t. to $V=12$
Tr 24	Feinstein	*UBV*	pe	9	material collected
6242	Andrews	*UBV*	pg+pe	17	obs. in prog.
6268	Andrews	*UBV*	pg+pe	17	obs. in prog.
H 10	Lyngå (**77**)	*UBV*	pg+pe	9·5	
6383	The (**82**)	*BV*	pg	14	
	Evans	*UBV*	pg+pe	16	pg to 19, s.t. to 10
	Graham	Hβ	pe	11	
Tr 28	The, Stokes	*UBV*	pg+pe	16	obs. in prog.
6404	The, Stokes	*UBV*	pg+pe	16	obs. in prog.
6405	Talbert (**83**)	*UBV*	pe	14	26 stars. age
6416	The, Stokes	*UBV*	pg+pe	16	obs. in prog.
6425	The, Stokes	*UBV*	pg+pe	16	obs. in prog.
Basel 5	Svolopoulos (**84**)	*UGR*	pg	15	
IC 4665	Abt, Snowden (**85**)			11·6	s.t., r.v., 35 stars
	Alcaino (**86**)	*UBV*	pe	11·5	37 stars *c–m*
	McCarthy, O'Sullivan	*BV*	pg		obj. prism s.t.
	Crawford	*uvby* Hβ			material collected
	Golay	$UBB_1B_2VV_1G$	pe	10	
6451	Svolopoulos (**84**)	*UGR*	pg	15	
Tr 31	Svolopoulos (**84**)	*UGR*	pg	15	
6514	Maffei (**87**)				var. stars
6520	Svolopoulos (**84**)	*UGR*	pg	15	
6530	Hiltner, *et al.* (**88**)			10·8	s.t. 25 stars
Cr 469	Grubissich (**89**)	*UGR*	pg	17	
6603	Grubissich	*UGR*	pg	18	
6611	Crawford	*uvby* Hβ			obs. in prog.
	Walker, G. A. H.				s.t., EW Hγ
	Grigoryan				pol.
6618	Maffei (**87**)				var. stars
Tr 33	Grubissich (**89**)	*UGR*	pg	18	
6633	Wallerstein, Conti (**14**)				chem. comp. 1 star
	Wallerstein, *et al.* (**15**)				r.v. 1 star
	Golay	$UBB_1B_2VV_1G$	pe	10	
	Grigoryan				pol.
	Mathews (**21**)	*V*	pg	13	
IC 4725	Graham	Hβ	pe	10	16 stars
	Grubissich	*UGR*	pg	16	
	Landolt (**90**)	*BV*	pg	14	1401 stars, *c–m*, *L*(*M*),
	Serkowski (**17**)		pe	11·7	pol. in *B*, V
	Wallerstein, Conti (**14**)				chem. comp. 2 stars
IC 4756	Alcaino (**86**)	*UBV*	pe	11·0	100 stars *c–m*
	Hildajat	*BVI*	pg		obs. in prog.
6683	Yilmaz (**91**)	*UGR*	pg	15	
Tr 35	Yilmaz (**92**)	*UBV*	pg	15	
6694	Grubissich	*UGR*	pg	16	
Basel 1	Grubissich (**93**)	*UGR*	pg	15·5	
	Fenkart (**94**)	*UGR*	pg	17·5	
6704	Grubissich (**93**)	*UGR*	pg	16	
6709	Mathews (**21**)	*V*	pg	13	

Observer and references (see end of table)	Photometry, method and limiting magnitude			Other data obtained, remarks
Bronkalla (**95**)	*UBV*	pg + pe	12·9	260 stars. Cl. not real
Mathews (**21**)	*V*	pg	13	
Svolopoulos (**96**)	*UGR*	pg	17·5	
Svolopoulos (**96**)	*UGR*	pg	18	
Batten				s.t., r.v., EW Hγ
Kinman (**97**)	*BV*	pg + pe	20	s.t., 16 stars. Old cl.
Chincarini, Walker, M. F.	*UBV*	pe	16	
Dolidze, Lypareva (**98**)				14·6 red stars in area
Barkhatova, *et al.* (**99**)	*UBV*	pe	16·5	120 stars. Similar to NGC 7789
Lindoff	*UBV*	pg + pe	14·5	plates taken
Mathews (**21**)	*V*	pg	13	
Serkowski (**17**)		pe	11·7	pol. in *B*, *V*
Walker, G. A. H.				s.t., EW Hγ
Basel Observatory	*UBV*	pg	16	
de Vegt				p.m. plates taken
Batten (**100**)				s.t., r.v., EW Hγ 11 stars
Golay	$UBB_1B_2VV_1G$	pe	10	
Grigoryan	*B*			pol.
Mathews (**21**)	*V*	pg	13	
Serkowski (**17**)		pe	11·7	pol. in *B*, *V*
Mathews (**21**)	*V*	pg	13	
Elst (**101**)	*I*	pg		plates taken
Grigoryan				pol.
Mathews (**21**)	*V*	pg	13	
Crawford	*uvby* Hβ			obs. in prog.
Grigoryan				pol.
Lawrence, Reddish (**102**)	*UBV*	pg + pe	15	
Mathews (**21**)	*V*	pg	13	
Walker, G. A. H.				s.t., EW Hγ
Crawford	*uvby* Hβ			obs. in progress
Batten				s.t., r.v., EW Hγ
Grigoryan				pol.
Artyukhina, Kholopov (**103**)	*B*		16·6	star counts
Barkhatova, Steinberg (**104**)	*UB*		16·5	structure
Larsson-Leander (**105**)	*BV*	pg + pe	15	*c–m*, mag. errors
Fenkart (**106**)	*UBV*	pg	16	*c–m*
Grigoryan				pol.
Becker (**107**)	*UBV*	pg	16	
Sobhy	*UBV*	pg	16	
Evans, Meadows (**108**)				r.v. 16 stars, sp. mot.
Sharov (**109**)	*B*		17·2	structure
de Vegt				p.m. plates taken
Golay	$UBB_1B_2VV_1G$	pe	10	
Lavdovsky (8)				p.m., mem., cl. mot.
Basel Observatory	*UBV*	pg	16	
Larsson-Leander	*BV*	pg + pe	16	s.t.
Becker (**110**)	*UBV*	pg	16	
Artyukhina, Kholopov (**111**)	*B*		16	structure, 18 var. stars
Mathews (**21**)	*V*	pg	13	
Basel Observatory	*UBV*	pg	16	
de Vegt				p.m. plates taken

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NGC	Observer and references (see end of table)	Photometry, method and limiting magnitude			Other data obtained, rem
7296	Basel Observatory	*UBV*	pg	16	
7380	de Vegt				p.m. plates taken
	Mathews (21)	*V*	pg	13	
	Morris, Walker, G. A. H.				s.t., r.v., EW Hγ
King 19	Grubissich (112)	*UBV*	pg	16	
7510	Mathews (21)	*V*	pg	13	
Mark 50	Grubissich (112)	*UBV*	pg	16	
7654	Bond				2 Be stars
	Elvius	*UV*	pg		stars around cl.
H 21	Barkhatova, Zhelvanova (113)	*VY*		16·8	mult. cl. with NGC 7788,
7788	Becker (114)	*UBV*	pg	16	
	Barkhatova, Zhelvanova (113)	*VY*		16·8	mult. cl. with H 21, NGC
	Mathews (21)	*V*	pg	13	
7789	Starrfield (115)	*BV*	pg+pe	12·8	var. star search
	Woolley				p.m. 2000 stars
7790	Barkhatova, Zhelvanova (113)	*VY*		16·8	mult. cl. with H 21, NGC

Abbreviations to Table 2

abs. = absolute
cl. = cluster
c − m = color-magnitude diagram
em. = emission
EW = equivalent width (of)
HR diag. = Hertzsprung-Russell diagram
int. = intensity
L(*M*) = luminosity function
mem. = members, membership
mot. = motion
mult. = multiple
obs. = observations
obj. = objective
P = period
pe = photoelectric
pg = photographic
p.m. = proper motion
pol. = polarization
prog. = progress
rot. = rotation
r.v. = radial velocity
s. bin. = spectroscopic binary (ies)
sel. = selective
sp. v. = space velocity
s.t. = spectral type
tot. = total
var. = variable
w/in = within

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New Clusters

Twenty-two new open clusters have been found by Hogg (**25**) on plates taken with the 74-inch (188 cm) reflector of the fields of clusters in Trumpler's list for declination $< -45^{\circ}$.

Lyngå (**26**) has surveyed the region from Centaurus to Norma, finding 14 new clusters.

Czernik (**27**) has found 45 new clusters, and King (**28**) five new clusters, both from studies of the plates of the Palomar Sky Survey.

Lodén reports that in the course of the Stockholm Observatory survey of the Southern Milky Way, a number of new clusters and associations have been found. Information on these objects (coordinates, size, number of stars, photographic and photovisual magnitudes to $m_{pg} \sim 14$ and rough spectral types of the brightest stars) will be supplied by him on request.

PHOTOMETRIC WORK

Important photometric investigations of old clusters have been made by Eggen and Sandage (**29**) and by Kinman (**30**).

In an extensive study of NGC 2682, Eggen and Sandage find that the discontinuity in the evolving portion of the main-sequence, previously suspected in NGC 752 and NGC 2477, is apparently real and may be related to a rapid evolution of the star between the depletion of hydrogen in the core and the onset of hydrogen burning in the shell. In addition, proper motion and spectroscopic data confirm the membership of the 'blue stragglers'-stars on or near the main-sequence above the turn-off point. Those could be either stars younger than the majority of members or objects in which complete mixing occurs. The data have also been used to derive reddening and blanketing corrections.

Kinman has observed NGC 6791 which proves to be similar in age to NGC 188. Novel features of this cluster include: (1) A sequence of blue subgiants whose membership is established from radial velocity measures, and (2) an incipient blueward extension of the red-giant branch, perhaps due to stars in a post red-giant stage.

Gray (**31**) has computed integrated magnitudes and colors of 67 open clusters from published photometry of their individual stars.

Schmidt-Kaler has extended Gray's work by calculating integrated magnitudes and colors of clusters having very large diameters. Large diameter clusters lie on a rather well defined intrinsic line in the color-color diagram. In the color-magnitude diagram, they are bounded by a well defined upper envelope: $M_v = -9{\cdot}4 + 4{\cdot}5\,(B-V)_0$. Application of these results to the photoelectric photometry of the 'globular' clusters in M 31 and M 33 shows that ten clusters in M 31 and eleven in M 33 are young open clusters, and yield results for the reddening of these objects of $E_{B-V} = 0{\cdot}12 \pm 0{\cdot}04$ and $0{\cdot}08 \pm 0{\cdot}03$ for M 31 and M 33, respectively. The absorption-corrected distance moduli obtained by this method are: $m - M = 24{\cdot}6 \pm 0{\cdot}3$ for M 31 and $24{\cdot}5 \pm 0{\cdot}4$ for M 33.

Schmidt-Kaler has also observed integrated magnitudes and colors (*UBV*, *ubvy* Hβ) of 41 open clusters photoelectrically at Kitt Peak using different diaphragms. The measures appear to give rather accurate reddening estimates and estimates of metal content. Also observed were 25 dBe stars in open clusters, to locate their position in the color magnitude diagram. These stars are found to occupy a strip about 1·5 magnitudes above the zero-age main-sequence.

Schmidt-Kaler and Vogt have completed the iris-photometer and coordinate measurement of all stars (about 4000) within 1° around h and χ Per down to 17·5 magnitude.

Smak (**32**) has observed T Tauri stars and faint stars in NGC 2264 and NGC 6530 using a special blue filter to eliminate the effect of line emission. He finds that for the 30 stars measured in each cluster down to $V = 15$, the B observations are not appreciably affected by line emission, unlike the 26 T Tau stars in the Taurus cloud also observed with this system. However, it has been pointed out by Aveni (**33**) that the special filter used by Smak does not

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eliminate all T Tau emission lines and is thus only partly effective in distinguishing line-emission effects.

Becker (34) has shown that too large a value of the ratio of total to selective absorption may be obtained because of: (1) intrinsic scatter in the color-magnitude diagrams of clusters and associations and, (2) the admixtures of non-member stars. It is concluded that the large ratio of total to selective absorption found by Johnson in III Cep and I Ara may result from the inclusion of non-members.

During the present report period, there has been a marked increase in the amount of work done on the polarization of the light of cluster stars, as indicated in Table 2. Serkowski (35) finds that a correlation between reddening and polarization is found only for IC 4725 and the association VI Cyg, while Grigoryan concludes that stellar (as opposed to interstellar) polarization exists for the stars of NGC 457.

Spectrographic Work

McCarthy and Treanor (36) have published a catalog of 125 red stars which they have observed in the vicinity of the Pleiades using the Vatican Schmidt. Of these, 27 stars fainter than $B = 16$ are considered to be probable members of the cluster. Image tube spectra of three of the latter group have been obtained with the Perkins-Lowell 72-inch (183 cm) reflector (37) and each of them shows the characteristic features of an M dwarf. For six stars of the Vatican catalog, flares have been observed by Haro at Tonantzintla and Rosino at Asiago.

Radial velocity observations of the OB stars in the direction of IC 1805 are being studied by Underhill. Preliminary results indicate that these stars are spread along a string and do not form a compact cluster near IC 1805.

M. F. Walker has continued spectrographic observations of UV excess stars in the Orion nebula and NGC 2264. Particular attention was given to SU Ori, which is one of the more active variables of the 'inverse P Cyg' or 'YY Ori' type. It was found that a correlation exists between the brightness of the star and the visibility of the redward-displaced absorption lines, these lines being visible at maximum and invisible at minimum light.

Roxburgh, *et al.* (38) have described a method whereby it is possible to discriminate between line broadening due to the degree of intrinsic rotation and to the aspect effect for stars in clusters having the same chemical composition, age, and distance. The method has been applied to stars in Praesepe, and the zero-rotation main-sequence derived.

Weaver and Ebert (39) have used the existing spectral types and photoelectric photometry of clusters to recalibrate the absolute magnitudes of the MK spectral types of stars in the range from O5 to A0.

Greenstein (40) has studied spectra of the bright red giants in NGC 188 and NGC 2682. The spectra are normal except that the color excess indicated by the spectral types and colors of the giants is greater than that of stars near the turnoff point of the main sequence.

Variable Stars

Since the subject of variable stars in clusters is covered in the report of Commission 27, a detailed account will not be given here. However, several of the investigations of variables in open clusters are referred to in Table 2. In addition, Efremov (41) has studied the Cepheids known to be related to clusters and has found a weak correlation between the periods of the Cepheids and the ages of their clusters, shorter periods corresponding to greater age. Starikova (42) also finds an indication of a correlation between the periods of Cepheids in clusters and the absolute integrated magnitude of the cluster.

Proper Motions

Guetter and Upgren report that first epoch plates are being taken of a number of open clusters with the 61-inch (155 cm) Astrometric Reflector of the U.S. Naval Observatory. After second epoch plates have been obtained, all plates will be measured on the automatic measuring engine for proper motion. The limiting measurable magnitude is about 18. Three-color photometry as well as radial velocities of the brighter stars will be obtained for some of the clusters in the interval between the first and second epoch plates. For some clusters, an extended region surrounding the cluster is being covered by more than one field in order to determine whether the cluster possesses a halo of faint stars of small mass. The existence of such a halo has been suggested by several investigators as a result of equipartition of energy among the member stars and from the disruption of the clusters by passing stars and clouds and the tidal force of the Galaxy. The small measuring errors achievable with automatic measurement of the plates will make it possible to obtain reliable separation of members from field stars with an interval between epochs of about 10 to 15 years, in most cases. For a few nearby clusters, an interval of about 30 years should make it possible to observe differential motions between different types of stars in the clusters.

Lavdovsky (**43**), continuing the work described in the last report, has used the proper motions from his catalog (**44**) to study the membership of stars in several clusters. In particular, he finds that NGC 6882 and NGC 6885 are two clusters at different distances and that NGC 1907 and NGC 1912 form a single system.

Vasilevskis, Saunders and Balz (**45**) have determined relative proper motions of 245 stars in the extremely young cluster NGC 2264. One hundred and forty-five stars were found to probability of have a membership greater than 0·5. The results confirm the conclusion by M. Walker (**46**) that stars later than Ao lie above the main-sequence; the five yellow giants in the cluster are found to be field stars, however. This result is extremely important since it provides a second case in which the membership of the faint stars lying above the main-sequence of a young cluster has been definitively established, the first being the study of the Orion nebula cluster by Strand (**47**). The observations of NGC 2264 have the advantage of extending to a fainter limiting absolute magnitude than do those in Orion and are thus capable of demonstrating the membership both of very red stars lying far to the right of the main-sequence in the color-magnitude diagram, and a number of relatively bluish stars which lie below the main-sequence. Proper motions in a second very young cluster, IC 1805, have also been measured by Vasilevskis, Sanders, and van Altena (**48**). In this case, determination of the color-magnitude diagram of the members is difficult owing to variable reddening. However, there is some indication that the age of the cluster may be less than that of NGC 2264.

As described in the last report, second epoch astrometric plates were obtained at Mt Wilson by Woolley and Murray of fields photographed by van Maanen with the 60-inch (152 cm) reflector. Reduction of this material has continued, and the proper-motions referred to in Table 2 for the clusters: Hyades, NGC 752, NGC 2168, NGC 2682, and NGC 7789, by Allchorn, Blackwell, Cannon, Clements, Corben, Lowne, Murray, Symms, Wayman, and Woolley, are derived from this material.

At Hamburg, de Vegt is investigating absolute proper-motions and space-velocities of a number of clusters; these are enumerated in Table 2. The material used in all of these studies is the following: First epoch, newly reduced data from the Carte du Ciel plates (Vatican zone). Second epoch, plates taken in 1965 with the Hamburg Schmidt telescope. It has been found that by using only the inner region of the Schmidt plates, and with a difference in epochs of 50 to 60 years, the cluster motion may be determined with a mean error of $\pm 0''.002$ per year.

Luminosity Function

The structure of NGC 188 has been studied by Sharov (**49, 50**) and by Barkhatova and Zinina (**51**) as indicated in Table 2. These authors find that the cluster, like NGC 752, NGC 2099 and NGC 2682 discussed in the last report, consists of a nucleus and a wide corona. The luminosity function of NGC 188 has also been determined and is found to have two maxima, at $M_B = +3$ and $M_B = +2$. The 'blue-stragglers' are found to be members of the cluster.

Similar studies of the structure of three clusters have been carried out by Kholopov and Artyukhina. The references are given in Table 2. The results of this study may be summarized in the following table:

NGC	Radius of Nucleus	Radius of Corona	Number of Stars
752	$25' - 35'$	$114'$	610 to $B = 15{\cdot}8$
6939	$16'$	$85'$	3400 to $B = 16{\cdot}8$
7243	$20'$	$75'$	130 to $B = 12{\cdot}9$ (counts to $B = 16{\cdot}1$)

In addition, the same authors have studied the luminosity function of NGC 2682 and its variation with distance from the center of the cluster.

The bright end of the luminosity function in 52 galactic clusters has been studied by Gray (**52**) who finds a change in slope with age of the cluster which can be explained in terms of the evolution of the stars. A similar investigation has been made by Martinet (**53, 54, 55**) who, starting from the observed luminosity functions in open clusters, has derived the form of the initial luminosity function, taking account both of the ejection of stars of small mass from the cluster and the evolution of the stars of large mass during the life of the cluster.

Dynamical Models

Bouvier (**56, 57**) has studied the steady state of isolated unrelaxed spherical systems along lines similar to those followed independently by Veltmann (**58**) Classification of the various possible anisotropies in the velocity distribution was made and compared with the generalized Schuster model. Bouvier (**59**) has also investigated the effect of a finite velocity of escape on the Schwarzschild ellipsoidal law for the velocity distribution in a system having no mean motions or undergoing differential rotation.

King (**60, 61**) has calculated self-gravitating cluster models whose cutoff velocity is determined by a finite tidal limit. Additional models have been calculated with a mixture of nine stellar groups of different mass. Models with isotropic velocity distributions fit the extensive star counts that are now available. The only discrepancy is an excess of brightness at the centers of the most concentrated clusters. This cannot be accounted for by anisotropy of the velocity distribution, which has very little effect in the cluster center. There must instead be an excess of mass at the cluster center. The observations can be satisfied by models that attribute the extra mass either to gas or to binaries concentrated at the center.

Prata is modifying King's models to include anisotropy in the velocity distributions.

Radio Observations

Howard and Westerhout (**62**) are conducting a program to determine the neutral hydrogen content of open clusters using the NARO 300-feet (91 m) radio telescope. Fifty clusters with diameters $\leq 20'$ have been observed and H I has been detected in about two-thirds of these. H I is found in both young and old clusters, but few young clusters do not have H I.

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Schwartz (**63**) has observed 13 open clusters and their immediate surroundings with the Bonn 25-meter radio telescope for interstellar neutral hydrogen. The expected profile has been calculated from the profiles at positions of equal distance from the cluster center and from parabolic fits for diagonals through the cluster center. H I is present in all clusters studied that have an age of 25×10^6 years or less, while no cluster older than 150×10^6 years had detectable amounts of H I. The optical velocities of the clusters are within 5–10 km s^{-1} of the means velocities of the H I clouds associated with the clusters. In some cases (e.g. NGC 129) there are indications of an expansion with a velocity of about 7 km s^{-1}. In general, the neutral hydrogen gas extends over a region which is about three times the optical diameter of the cluster.

Space Distribution

Clube has examined the radial velocities of B stars in Eggen's catalog and proper motions of A stars in the *Cape Catalog of Proper Motions of* 20 843 *Stars*. This has revealed a common streaming motion for members of the Gould Belt, equal to that of the Pleiades group. Gould's Belt is regarded as being a narrow projection from the lower edge of the Orion spiral arm, expanding towards $l_{II} = 0°$, $b_{II} = +20°$. The kinematic age of Gould's Belt is about $3{\cdot}7 \times 10^7$ years.

The galactic structure in the region from Centaurus to Norma has been investigated by Lyngå (**64**) on the basis of cluster data, while Alter (**65**) has identified seven clusters with a spiral feature extending from Carina to Scutum.

Evolution

A complete discussion of stellar evolution is given in the report of Commission 35, so that only selected references will be mentioned here.

The problem of the spread in ages of stars in clusters has continued to attract considerable attention. Williams (**66**) has constructed a theoretical color-magnitude diagram for a cluster having a spread in the ages of formation of its stars, and finds that this spread in age assumption does not explain the existence of the 'blue straggler' stars. The problem of the unusually long main-sequence in objects like the Pleiades and h and χ Per has been considered by Reddish (**67**) who concludes that in such objects the bright stars may have been formed by accretion from the fainter ones. Observational evidence on this point may be provided by the work of Golay (**68**) who has observed the Pleiades on his seven-color system and finds an indication that the cluster may contain two groups of stars having different ages.

The problem of the pre-main-sequence stages of stellar evolution also continues to be of great importance. Penston (**69**) has reviewed the comparison of the various theories of pre-main-sequence evolution with the observations of NGC 2264 and NGC 6530 and concludes that the evidence favors the Hayashi theory rather than Henyey-type contraction or the theory of Faulkner, Griffiths, and Hoyle. Iben and Talbot (**70**) have calculated star formation rates in young clusters where most of the stars are still in the gravitational contraction stage. They find that the hypothesis of a spread in age or of continual creation does not conflict with the short time-scale associated with the Hayashi tracks. A difficulty in all of the theories remains the existence, particularly in NGC 2264, of faint member stars near and even below the main-sequence. While stars near the main-sequence might be interpreted as being older than the other members of the cluster, no explanation of the stars below the main-sequence exists. However, spectrographic observations by M. F. Walker (**71**, and unpublished) show that many of the faint stars in NGC 2264 and the Orion nebula, including those below the main-sequence, possesses a blue continuum. Thus, for these stars, at least, the observed $B-V$ colors will give too high an effective temperature. Correction for this effect will probably move these stars from below the main-sequence to a position far enough to the right to accord with a model involving a reasonable spread in ages of the member stars.

Dluzhnevskaya (**72**) has studied the distribution functions of the colors of stars in clusters with ages between 0 and 10^8 years. Two cases were considered: (1) evolution with constant mass, and (2) evolution with mass loss. The second case was found to give better agreement between theory and observations, but it is recognized that one weakness of the investigation is the assumption of a time-independent initial luminosity function.

Wildey has continued his investigation of h and χ Per with particular emphasis on the apparent disagreement between the observed ratio of the numbers of early to late supergiants and the much smaller ratio resulting from the rapid evolution due to the neutrino pair production and photoneutrino processes predicted by the conserved-vector current theory of weak-coupling interactions. Statistical studies of the distributions of the early and late supergiants near h and χ Per indicate that the stars are indeed part of the same spatial system, while color photographs indicate that incompleteness is not a significant source of error in the observed early to late ratio.

Kholopov (**73, 74**) regards open and globular clusters as links in a single evolutionary chain, the differences between them being determined chiefly by their mass and age. The general character of the evolution of stars does not depend on their chemical composition. There is no single-valued relationship between the metal content and the age of stars. The relationship between the metal content of the stars in globular clusters and the maximum distance of the latter from the center of the Galaxy indicates that the stars were born from a diffuse medium in the proto-galaxy in which differentiation of elements according to weight had already occurred.

GLOBULAR CLUSTERS

(Prepared by L. Rosino)

Arp (**75**) has published in Vol. V of *Stars and Stellar Systems* a chapter on the intrinsic and kinematical properties of the globular clusters of our own Galaxy. Table 1 in his article gives for 120 clusters the best data obtainable on absorption, diameter, distance modulus, integral magnitudes, colors, spectral type and radial velocity.

Integral Photometry

Van den Bergh (**76**) has determined *UBV* magnitudes for 49 globular clusters at Cerro Tololo inter American Observatory. He has found that the observed colors may be used to define a reddening-independent metallicity index $Q = (U-B) - 0{\cdot}72\ (B-V)$, which can easily be correlated with other indicators of metal content. For 14 metal-rich clusters the radial velocity dispersion has been found to be 75 km s^{-1} compared to 162 km s^{-1} for 56 metal poor clusters. The intrinsic colors of globular clusters in M 31 and the Galaxy are well represented by the relation $(B-V) = Q + 1{\cdot}00$. For 63 clusters with $\csc|b| < 10$ van den Bergh has obtained $E(B-V) = 0{\cdot}060 \csc|b| - 0{\cdot}009$. Finally there is some indication that the frequency function of Q values in M 31 differs from that in the Galaxy in the sense that M 31 contains fewer metal-poor clusters than does the Galaxy. The data, however, are insufficient to establish this point with certainty.

P. McClure (**77**) has used the 74-inch (188 cm) reflector of the D. Dunlap Observatory to show that the intermediate-band color index c (λ 3800/λ 4150) may be used to measure the metallicity of globular clusters.

Researches on the colors of globular clusters have also been made by Koehler (**78**) at Mt Stromlo Observatory who has found correlations of the G-band index with metallic content and intrinsic colors. Schmidt-Kaler (**79**) has observed at Kitt Peak 36 globular clusters north of -30° in Stromgren's system *uvby* using various diaphragms. For 15 of these Hβ has been measured photoelectrically. The observations appear to give a measure of the metal content and reddening and an unambiguous spectral-type-equivalent of the clusters. The intrinsic colors of 20 globular clusters have been determined by comparison with distant early-type stars or galaxies. The globular clusters occupy a triangular region in the *UBV* two-color diagram partially overlapping with that of intermediate-age and old open clusters. The median absolute magnitude of RR Lyrae in seven globular clusters of known reddening appears to be $\overline{M}_v = +0{\cdot}35$. Menzies at Mt Stromlo has also observed *UBV* colours of globular clusters and hopes to publish these shortly. Integrated *UBV* magnitudes of the Fornax dwarf galaxy have been reported by Hodge (**80**). The absolute magnitude is $M_v = -8{\cdot}0$ (in our Galaxy $M_v \sim -8{\cdot}2$).

Light distribution, Luminosity function

Mlle Rousseau (**81**) in Haute-Provence has measured with a series of diaphragms of different size *UBV* magnitudes of 22 globular clusters. I. R. King (**82**) has reported on the photoelectric observations of nine globular clusters (NGC 5024, 5272, 5904, 6205, 6218, 6254, 6341, 7078, 7089) made at Mt Wilson through five concentric circular apertures of various diameters and also with the same small-sized diaphragm at different points of the cluster. Profiles giving the surface brightness as a function of the distance from the center have been derived. Additional photoelectric measurements have been made by J. L. Hitchcock in three clusters. King and his associates have also completed their star-counting program in globular clusters and the results should be in print by the time this report appears. The program includes 164 counts in 54 clusters.

The luminosity function for M 13 has been obtained down to $V \sim 19$ by means of star counts on plates taken with the 74″ Okayama reflector by M. Simoda and H. Kimura (**83**). Particular attention has been paid to the counting method. Counts have been made within a ring having an outer radius of 8′ and an inner radius of 2′ to 4′. Significant differences have been found between the luminosity function of M 13 and that of M 3 as determined by Sandage (**84**), the luminosity function in M 13 having a steeper gradient than in M 3. By combining the observed luminosity function with the population II stellar models by Faulkner and Iben (**85**) some interesting results are obtained on the lifetime for horizontal branch stars.

Photoelectric surface photometry in the *PVI* system has been made by Kron (**86**) at Mt Stromlo on the rich globular cluster 47 Tucanae. The observations confirm that the radial surface brightness gradient follows de Vaucouleurs law (**87**) as already shown by Gascoigne and Burr (**88**). Kron, however, finds that the central brightness of 47 Tuc is nearly as high as is that of the more condensed elliptical galaxies. The radial color gradient is small as previously found by Kron and Mayall (**89**) for 48 clusters.

The space distribution of bright stars in a cluster (M 92) has been determined by star counts by Blagikh (**90**) who has compared his results with those obtained by Kholopov (**91**) for M 3. Equidensity curves of M 13 have been derived by Kadla from plates taken at Tautenburg and Flagstaff; the author has pointed out the dependence of these curves by the axial ratio b/a.

Color-magnitude diagram

Much work has been done in this important field which is strictly connected with the problems of stellar evolution. Sandage and Katem (**92**) have determined *B* and *V* magnitudes for 293 stars in the moderately strong-lined globular cluster NGC 6171 (Morgan's class V). A similar research has been made by Sandage and Smith (**93**) on 304 stars of the cluster NGC 6712, which also belongs to Morgan's class V. The principal differences presented by the $c-m$ diagrams of these clusters in comparison with halo clusters are: (*a*) strong concentration of stars on the red side of the RR Lyrae gap; (*b*) little steepness of the giant branch which, at $(B-V)^\circ = +1{\cdot}4$, rises only 2 magnitudes above the horizontal branch, while in halo clusters it rises 3 magnitudes; (*c*) Intrinsic redward displacement of the giant and subgiant sequences in comparison with clusters having lower metal abundance.

Arp (**94**), in a photometric research on the properties of the Galactic nucleus, has given the color-magnitude diagram of NGC 6522. The absence of stars on the blue side of the RR Lyrae gap identifies the cluster as a metal-rich system such as NGC 6356 and 47 Tuc. After correction for reddening, a distance of 7·5 kpc is found.

Sandage and Walker (**95**) have determined *UBV* magnitudes for stars brighter than $V \sim 17$ in M 92. The horizontal branch redward of the variable star gap is absent, as is characteristic of low metal-abundance clusters. A new and unexpected feature in the color distribution for stars in the subgiant and asymptotic-giant branch is the fact that stars of equal $B-V$ in the two branches differ by as much as 0·25 in $U-B$. An unknown magnitude source of continuous opacity or abnormal line strengths for stars in one branch compared with the other could explain the difference. Similar results have been found also in an analysis of three-color magnitudes for M 3 (**96**).

Extensive photometric studies on individual stars in globular clusters have been made by Cuffey (**97, 98**) on M 53 (*B*, *V*, $c-m$ diagram; color of bright stars in nucleus) and in ω Centauri by Woolley (**99**), Dickens and Saunders (**100**). Geyer (**101**) has also done three-color photometry (*UBV*) for 400 stars in ω Centauri from 10·9 to 15·7 *V* on plates taken at the Boyden Observatory. The color-magnitude diagram has the characteristic features of a halo cluster, while the two-color diagram shows an effect similar to that found by Sandage and Walker in M 92.

Color-magnitude diagrams have been published for NGC 6522 (**102**), and for the loose cluster Pal. 13 (**103**). Work is in progress for M 15 (Sandage and Katem), 47 Tuc (**104**), NGC 4372 and NGC 7099 (P. J. Andrews, Radcliffe Observatory) (**105**). A good deal of work is currently in progress at the Mt Stromlo Observatory. (**106**), as shown in the following table:

Cluster	*Observer*	*Photometry*	*Method*	*Limiting V Magnitude*
NGC 362	Menzies	*UBV*	pe + pg	16
3201	Menzies	*UBV*	pe + pg	16
5139	Brooke	*VRI*	pe	14
6266	Gascoigne	*VB*	pe + pg	17·5
6397	Gascoigne	*UBV*	pe	16
6397	Gascoigne and ass.	*VRI*	pe	14
6723	Menzies	*UBV*	pe + pg	19
104	Brooke	*VRI*	pe	14
104	Menzies	*UBV*	pe	16

Spectra

An extensive study of the spectra of horizontal-branch stars in the nearest globular cluster, NGC 6937 ($m - M = 12{\cdot}0 \pm 0{\cdot}3$) has been made by Searle and Rodgers (**107**) at Mt Stromlo. The stars have been shown to be metal-deficient by a factor of about 100 and evidence has been presented that they are also helium-deficient. Masses of 1·3 $\mathfrak{M}_\odot$ have been found by discussing the hydrogen line strength. Using spectral data by Helfer, Wallerstein and Greenstein (**108**), Pagel (**109**) has redetermined abundances in the red giant Barnard III-13 in M 92. Results confirm that the Fe/H ratio is about 1/200 of the solar value and indicate

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unchanged solar abundances relative to Fe for Mg, Ti, V, Cr, Ni, Sr, Y and Zr. Barium seems over-deficient relative to iron by a factor of about 3.

Other spectroscopic investigations of the brightest stars in the clusters NGC 4372 and 7099 are in progress at the Radcliffe Observatory.

Proper motions, Radial velocities, Dynamics

A series of dynamical researches on ω Centauri have been made in the last three years. Harding (**110**) on spectra taken at the Radcliffe Observatory. has determined 74 radial velocities of 40 individual stars, of which 31 proved to be cluster members. Proper motions of individual stars have been published in *R. O. Annal* no. 2 and discussed by Murray, Jones and Candy (**111**). Through a statistical procedure, cluster members were separated from field stars. A paper of Woolley and Dickens (in press) will finally discuss the structure and dynamics of the cluster. A comparison of stellar distribution with radius will be made with the theoretical models.

Proper motions in NGC 6522 (**112**) have been determined by Clube and are in progress for 1200 stars of 47 Tuc.

Theoretical studies on the dynamics of globular clusters have been published by Matsumani (**113**) who has shown correlations between kinematical and physical characteristics (energy, angular momentum, integrated spectral type, diameter and concentration class) and by Hénon (**114, 115**) who has computed theoretical models for isolated clusters. Hénon is presently working on a new approach to cluster dynamics, using the Monte Carlo method (**116**). The approach achieves a substantial reduction of computing time and will probably permit the treatment of the full dynamical problem without restrictive hypotheses.

Variable stars

The work on variable stars in globular clusters will be extensively reported by H. Sawyer Hogg in Commission 27; only a short and incomplete account is given here.

New variable stars in or near globular clusters have been found by Wilkens (**117**) (ω Cen, NGC 3201), Kurochkin (**118**) (NGC 6171), Fourcade and Laborde (**119, 120, 121**) (NGC 5286, NGC 6352, NGC 1261, NGC 6624, IC 4499). An extensive study of the RR Lyrae variables in M 3 has been made by Szeidl (**122**) who has discussed light curves and periods for 112 stars of this type. Thirty-six of them show well pronounced changes. Wilkens (**123**) has examined the variations of periods of RR Lyrae stars in M 4. An investigation on the period changes of 150 variables in ω Cen, also by Wilkens, is just coming to its end. Studies on the variations of periods and light curves have also been made by Makarova and Akimova (**124**) (M 15) and by Margoni (M 53) (**125**). Photometry of RR Lyrae stars in clusters and period determinations have been made: in NGC 6712 by Sandage, Smith and Norton (**126**) and by Rosino (**127**); in ω Cen by Dickens and Saunders (**100**); in M 53 by Margoni (**128**); in M 14 by Sawyer Hogg and Welhau (**129**); in NGC 7006 by Rosino and Ciatti (**130**).

The long-period variables in globular clusters have been studied by Feast (**131, 132, 133**). By a critical examination of the existing data and by radial velocity determinations made at the Radcliffe Observatory he concludes that there are probably no known Me (Mira Type) variables with periods greater than about 220 days in globular clusters.

W. Lohmann (**134**) has made a general study of the period-luminosity relation for RR Lyrae stars in globular clusters, using the published material. For some clusters he has not found any definite linear relation between m and log P. For other clusters he has found relations which, however, are different from cluster to cluster and not so clearly defined as for the Galactic RR Lyrae stars.

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Miscellaneous

McCarthy and Treanor (**135**) have studied the faint cluster Abell 2 on direct plates taken in infrared with the Vatican Schmidt. The interstellar absorption on the cluster is likely to amount to 2 magnitudes. They conclude that the object may be a peculiar intergalactic cluster or an old open cluster located at the edge of the Galaxy.

Roeder (**136**) has examined the effect of helium content on the theoretical deviation curves. Since the helium content is known only with little accuracy, the distance modulus of globular clusters derived by comparison of the theoretical curves with the observations may be affected by an uncertainty of 0·2 magnitude, in addition to the errors of observation. Kholopov (**137**) has advanced some alternatives to the hypotheses of Schwarzschild and Sandage on the evolution of star clusters. One of the alternatives is that there may not be a unique initial luminosity function for all clusters.

Vogt (**138**) has investigated the interstellar hydrogen content in M 3, M 5 and M 13 by measures of the 21-cm line radiation. He has concluded that upper limits for the mass of neutral atomic hydrogen in these clusters are between 100 and 180 $\mathfrak{M}_{\odot}$. A similar result has been found by Goldstein (**139**) in M 13 with the Harvard 60 ft (9 m) reflector and maser radiometer.

Vorontsov-Velyaminov (**140**) has examined from a statistical point of view the globular clusters which surround many elliptical galaxies. He does not find any correlation between their number and the luminosity or mass of the parent galaxy.

Proposals

H. Wilkens (La Plata Observatory) proposes that equatorial and galactic coordinates of globular clusters be given in future for the Equinox 2000·0. He makes some interesting remarks on the subject and suggests that a Table for the rapid conversion of α and δ (2000) into l_{II} and b_{II} be calculated.

MISCELLANEOUS

The application of electronography to stellar photometry is being studied by Lallemand *et al.* (**141**) and by Kron and M. F. Walker. As a consequence of the linear relation, in electronography, between plate density and image intensity, Lallemand found a linear relationship between image density measured with a Schild-type photometer and the intensity of each star over a range of 2·5 magnitudes, beginning at the plate limit. Kron and Walker have found that by making a densitometer trace of each star image, it is possible to obtain a linear relation between intensity and area under the image profile over a range of at least magnitudes when the electronic image is recorded on Ilford G5 plates developed 5 minutes in D–19. A larger linear range may exist, since linearity holds on electronographic plates to densities of at least 3. The importance of such a technique in cluster photometry is obvious. Using an electronographic-type image-tube, it is only necessary to set up a few bright standards in the cluster; magnitudes of all fainter stars down to the plate limit may then be determined from the electronographic plates. In addition, the fine grain (track size) of the electronographic plates should make possible both higher accuracy of measurement and a fainter detection limit than are possible photographically, while the high speed of the electronographic system will make it possible for a Cassegrain reflector of moderate aperture to reach faint stars heretofore only observable with the largest reflectors.

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M. F. WALKER
President of the Commission

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