37. STAR CLUSTERS AND ASSOCIATIONS
(AMAS STELLAIRES ET ASSOCIATIONS)

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INTRODUCTION

The data contained in this report have been taken from two sources: (1) Information received from astronomers active in the field of Commission 37 in response to a circular letter mailed July 1969; (2) Surveys of special fields, prepared by W. Becker on "Open star clusters and spiral structure", by G. Larsson-Leander on "Clusters and stellar evolution", by M. Walker on "Young clusters", and by P.-B. Bouvier on "Dynamical models and numerical computations". It is a pleasure to thank them and all of those who have contributed to the preparation of this report.

CATALOGUES

G. Alter reports that after a long delay the second edition of the *Catalogue of Star Clusters and Associations.* (G. Alter, J. Ruprecht, V. Vanýsek), which was discussed at a meeting of our commission at the Congress in Hamburg (1964) (*Trans. IAU*, **12B**, 1966, 336), will now be published by Publishing House of the Hungarian Academy of Sciences. It is considerably enlarged, since it includes the contents of the annual Supplements published in *B.A.C.* between 1959 and 1967.

S. van den Bergh and G. L. Hagen initiate a project aimed at the production of an atlas of cluster colour-magnitude diagrams on the *UBV* system. For each cluster the area of the sky for which data are plotted is chosen in such a way as to optimize the contrast between the color-magnitude diagram of the cluster and that of the background stars. Furthermore, available radial-velocity and proper-motion data are used to eliminate as many field stars as possible. All diagrams will be printed on an uniform scale. To facilitate intercomparison of clusters each color-magnitude diagram will be printed on a separate card of size 21 × 23 cm.

R. E. White at Arizona has prepared a bibliography of all existing color-magnitude diagrams for globular clusters, including reproductions of the diagrams.

ASSOCIATIONS

Within the framework of a project for detection of intermediate-type stellar associations, a number of suspected objects (320) in the Southern Milky Way have recently been observed by L. O. Lodèn. There is a strong indication that a considerable number of these objects ("quasi-associations") do constitute physically real associations or clusters, which are too dispersed to be detected only by inspection of direct-photographic plates. They are disclosed at inspection of objective-prism plates, if two or more spectra of the same type are situated so close on the plate that they form a conspicuous configuration.

According to Pik-Sin The, the OB-associations Vul OB1 and Vul OB4 are located in about the same direction. Their estimated distances are 2 and 1 kpc, respectively. In the direction of these associations we also have the open star clusters NGC6823 and NGC6830. In collaboration with van Paradys, Pik-Sin The has begun the study of these associations in order to determine:

https://doi.org/10.1017/S0251107X00024007 Published online by Cambridge University Press

Table 1. Associations

Name	Observer and references	Photometry, method and limiting magnitude			Other data obtained, remarks
Vul OB1	Pik-Sin The, van Paradys	*UBV*		10·5	s.t. planned mag. 15
Vul OB1	Walker, Hodge (1968)	Hγ			s.t.
Vul OB4	Pik-Sin The, van Paradys	*UBV*		10·5	s.t. planned mag. 15
Cyg OB3	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Cyg OB1	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Cyg OB1	Walker, Hodge (1968)	Hγ			s.t.
Cyg OB1	Schewick				p.m. P Cygni
Cyg OB9	Walker, Hodge (1968)	Hγ			s.t.
Cyg OB2	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Cyg OB2	Walker, Hodge (1968)	Hγ	pe		s.t.
Lac OB1	Valtz, Dluzhnevskaya				HR diagram
Cep OB1	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Cep OB1	Walker, Hodge (1968)	Hγ	pe		s.t.
Cep OB3	Valtz, Dluzhnevskaya				HR diagram
Cas OB6	Walker, Hodge (1968)	Hγ			s.t.
Cas OB7	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Per OB1	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Per OB3	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Per OB2	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Per OB2	Valtz, Dluzhnevskaya				HR diagram
Aur OB1	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Aur OB2	Walker, Hodge (1968)	Hγ	pe		
Gem OB1	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Gem OB1	Valtz, Dluzhnevskaya				HR diagram
Mon OB1	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Mon OB2	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		
Ara OB1	Valtz, Dluzhnevskaya				HR diagram
Sco OB2	Valtz, Dluzhnevskaya				HR diagram

Abbreviations to Table 1. s.t. = spectral type; p.m. = proper motion; pe = photoelectric.

(1) Which of the OB-stars found in the direction of the associations belong to them.
(2) More accurately the distances of these associations.
(3) Whether there are any relations between the open clusters and the associations.

Van Schewick determined the absolute proper motion of the variable star PCyg and compared it with the proper motions of the open cluster IC4996 and the association Cyg OB1. The star is a probable member of the OB-association and its absolute magnitude is $M_v = -8{\cdot}1$.

Martinet (1969) has suggested that the high-velocity A-star 7 Sextantis could have been born in the upper-Centaurus Lupus association, $1{\cdot}5 \times 10^6$ years ago, and ejected from it as "run away" star.

G. A. H. Walker and S. M. Hodge (1968) carried out a study of the associations Aur OB2, Vul OB1, Cyg OB9, Cyg OB1, Cep OB1, Cas OB6, Cyg OB2. Spectral types and Hγ equivalent widths have been derived from low dispersion spectrograms of the brightest stars. The associations appear to be divided roughly into two groups. Associations in group 1 contain very bright HII regions and the spectra of their early B stars show stronger Hγ absorption than those of the corresponding stars in group 2 associations. Group 1 is probably younger than group 2, and radio-continuum and 21-cm surveys appear to support this. Trapezium-type systems occur in both groups; they contain at least one O star, and the B stars of latest spectral type do not appear to have contracted to the main sequence.

https://doi.org/10.1017/S0251107X00024007 Published online by Cambridge University Press

Table 2. Open clusters

NGC	Observer and references	Photometry, method and limiting magnitude			Other data obtained, remarks
129	Tsioumis, Poulakos				space distribution
188	Cannon (in press)				p.m.
	Sharov, Salukvadze				
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
457	Panorin, Starikova				
	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		in progress
559	Lindoff (1968)	*UBV*	pg + pe	14·5	
609	Burkhead	*UBV*	pg		photoelectric calibration
IC166	Burkhead	*UBV*	pg		photoelectric calibration
752	Cannon (in press)				p.m.
	Mavridis				space distribution
	Vasilyevsky				spectra
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
869-884 (h + χ Per)	Vasilyevsky				spectra
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
IC1805	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
957 (King 4)	Karimie (1968)			15·7	c-m
	Larsson-Leander				in progress
1245	Zakharova				
IC348	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
Pleiades (M45)	McCarthy, Treanor (1968)				mem, p.m., var, Hα, em
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
	McCarthy				s.t.
1502	Rufener *et al.*	$UBVB_1B_2V_1G$			in progress
1513	B.K.S.Z.				photometry
1528	Panorin, Starikova				
	B.K.S.Z.				photometry
	Larsson-Leander				in progress
1545	B.K.S.Z.				photometry
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
Hyades	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
	Nalimov				
	Vasilyevsky				spectra
	Kholopov				spatial density
	Straizys, Kavaliauskaite				evolution
1647	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
1662	Vasilyevsky				spectra
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		in progress
1746	Vasilyevsky				spectra
1907	Panorin, Starikova				
2099	Panorin, Starikova				
2129	V.K.P.F.K. *et al.*				absorption of light
2168	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
2169	Rufener *et al.*	$UBVB_1B_2V_1G$	pe		in progress
2244	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
Tr 5	Burkhead	*UBV*	pg		photoelectric calibration
2264	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
2281	Vasilyevsky				spectra
2301	van Schewick (1967)				p.m.
Cr 121	Feinstein (1967)	*UBV*	pe	10	
2362	Lloyd Evans		pe	12	

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Table 2 (continued)

NGC	Observer and references	Photometry, method and limiting magnitude			Other data obtained, remarks
2420	Cannon (unpublished)				p.m.
	Zakharova				
2483	Lindoff (1968)	*UBV*	pg + pe	15	
2489	Lindoff (1968)	*UBV*	pg + pe	15	
2506	Burkhead	*UBV*	pg		photoelectric calibration
2516	Feinstein, Mirabel	*UBVRI*	pe	11	materiel collected
2533	Lindoff (1968)	*UBV*	pg + pe	14·5	
2546	Lindoff (1968)	*UBV*	pg + pe	14·5	
Pismis 1	Lindoff (1968)	*UBV*	pg + pe	15·5	
2567	Lindoff (1968)	*UBV*	pg + pe	14·5	
2571	Lindoff (1968)	*UBV*	pg + pe	14·5	
2579	Lindoff (1968)	*UBV*	pg + pe	15	
Cr 185	Lindoff (1968)	*UBV*	pg + pe	15	
Praesepe (2632)	Tucker, Blackwell				p.m.
	Straizys, Kavaliauskaite				evolution
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
	Serkowski		pe		pol. 4 stars
2682 (M 67)	Murray (1968)				p.m.
	van Schewick (in press)				p.m.
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
	Serkowski		pe		pol. 6 stars
2818	Andrews		pe + pg	17	in progress, spectra of brightest stars
Tr 12	Lindoff (1968)	*UBV*	pg + pe	15	s.t.
3292	Andrews		pg + pe	16	in progress
Tr 14	Pik-Sin The	*UBV*	pg	13	in progress
Tr 15	Pik-Sin The	*UBV*	pg	13	in progress
Tr 16	Feinstein (1969)	*UBV*	pe	12	
	Pik-Sin The	*UBV*	pg	13	in progress
3532	Landolt				s.t., r.v.
	Serkowski		pe		pol. 4 stars
3680	Serkowski		pe		pol. 3 stars
3766	Landolt				s.t., r.v.
	Serkowski				pol. 3 stars
	Lloyd Evans		pg + pe	15·5	
3960	Lindoff	*UBV*	pg + pe	15	in progress
	Ardeberg	*UBV*	pe		32 stars within 3′ from centre
Coma Berenices	Straizys, Kavaliauskaite				evolution
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
4609 (Coal Sack)	Feinstein, Marraco	*UBV*	pe	13	material collected
4755	Panorin, Starikova				
	Serkowski		pe		pol. 30 stars
4756	Vasilyevsky				spectra
Stock 16	Lyngå (in press)	*UBV*	pe	12·5	s.t., r.v., OB-stars
5138	Lindoff	*UBV*	pg + pe	15	in progress
5460	Lindoff	*UBV*	pg + pe	15	in progress
Lyngå 2	Lindoff (1968)	*UBV*	pg + pe	14	
5617	Lindoff (1968)	*UBV*	pg + pe	14	
Hogg 17	Lindoff (1968)	*UBV*	pg + pe	14	
Tr 22	Lindoff (1968)	*UBV*	pg + pe	14	
Pismis 20	Lyngå (1968)	*UBV*	pe	13	s.t. OB-stars
6025	Feinstein	*UBVRI*	pe	12	material collected
	Lindoff	*UBV*	pg + pe	15	in progress

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Table 2 (continued)

NGC	Observer and references	Photometry, method and limiting magnitude			Other data obtained, remarks
6031	Lindoff (1968)		pg	16	
6129	Vasilyevsky				spectra
6134	Lindoff	*UBV*	pg + pe	15	in progress
6192	Lindoff	*UBV*	pg + pe	15	in progress
	Andrews		pg + pe	17	under observation
6208	Lindoff	*UBV*	pg + pe	15	in progress
6231	Andrews		pe + pg	17	in progress
	Feinstein, Ferrer (1968)	*UBV*	pe	10	
	Seggewiss (1968)	*UBV*	pe + pg	15·2	295 stars, nucl. of Sco OB1
6242	Seggewiss (1968)	*UBV*	pe + pg	13·5	128 stars
	Andrews		pe + pg	17	in progress, spectra of brightest stars
Tr 24	Seggewiss (1968)	*UBV*	pe + pg	13·5	northern section of Sco OB1
6268	Seggewiss (1968)	*UBV*	pe + pg	14·0	75 stars
	Andrews		pe + pg	17	in progress, spectra of brightest stars
6281	Lindoff	*UBV*	pe + pg	15	in progress
	Andrews		pe + pg	15	in progress, spectra of brightest stars
IC4651	Lindoff	*UBV*	pe + pg	15	in progress
6383	Lloyd Evans				var
TR 27	Pik-Sin The (in press)				distance
TR 28	Pik-Sin The (in press)				distance
6400	Lindoff	*UBV*	pe + pg	15	in progress
6405 (M 6)	Serkowski				pol. 5 stars
6416	Pik-Sin The (in press)				distance
6425	Pik-Sin The (in press)				distance
IC4665	McCarthy, O'Sullivan (1969)		pg		c-m
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
6494	Panorin, Starikova				
6530	Panorin, Starikova				
6611	Panorin, Starikova				
6613	Lindoff	*UBV*	pe + pg	15	in progress
	Vasilyevsky				spectra
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe		
6645	Lindoff	*UBV*	pe + pg	15	
IC4756	Seggewiss (1968)	*UBV*	pe + pg	14·2	471 stars
	van Schewick (in press)				p.m.
6705	van Schewick (in press)				p.m.
6716	Lindoff	*UBV*	pe + pg	15	in progress
IC4996	van Schewick (1967)				p.m.
	Rufener *et al.*	$UBVB_1B_2V_1G$			in progress
6716	Lindoff	*UBV*	pe + pg	15	in progress
6802	V.K.P.F.K. *et al.*				absorption of light
6811	Vasilyevsky				spectra
	Lindoff	*UBV*	pe + pg	14·5	in progress
6819	B.K.S.Z.				photometry
	Vasilyevsky				Spectra
	Lindoff	*UBV*	pe + pg	15	in progress
	King	*UBV*	pe + pg	16	
	Burkhead	*UBV*	pg		photoelectric calibration
6823	V.K.P.F.K. *et al.*				absorption of light
6834	V.K.P.F.K. *et al.*				absorption of light

Table 2 (continued)

NGC	Observer and references	Photometry, method and limiting magnitude		Other data obtained, remarks
Mel 227	Ardeberg	*UBV*	pe	51 stars within 20′ from centre, s.t.
6871	van Schewick (in press)			p.m.
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe	
6866	B.K.S.Z.			photometry
	Koroleva			p.m.
6913	V.K.P.F.K. *et al.*			absorption of light
6939	Cannon (in press)			p.m.
	Burkhead	*UBV*	pg	photoelectric calibration
7063	Sharov			
7086	V.K.P.F.K. *et al.*			absorption of light
7092 = M 39	Artyukhina, Kholopov			
	Straizys, Kavaliauskaite			evolution
	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe	
7142	van den Bergh	*UBV*	pe	
	Sharov			
7160	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe	
IC1434	Larsson-Leander			in progress
7654	V.K.P.F.K. *et al.*			absorption of light
King 11	Burkhead	*UBV*	pg	photoelectric calibration
7789	Cannon (1968)			p.m.
	B.K.S.Z.			photometry
	Vasilyevsky			spectra
	Tsioumis, Poulakos			space distribution
	Zakharova			
	Koroleva			p.m.
7822	Rufener *et al.* (1970)	$UBVB_1B_2V_1G$	pe	
Ru 58	Lindoff (1968)			

Abbreviations to Table 2. V.K.P.F.K. *et al.* = Voroshylov, Kolesnik, Polishtchuk, Fedorchenko, Kalandadze *et al.*, B.K.S.Z. = Barkhatova, Kuz'mina, Shashkina, Zakharova.
c-m = colour magnitude diagram; em = emission; pe = photoelectric; pg = photographic; p.m. = proper motion; pol. = polarization; r.v. = radial velocity; s.t. = spectral type; var = variable; mem = membership.

OPEN CLUSTERS

Proper motions

The relative and absolute proper motion of the young cluster IC4996 has been determined by van Schewick (1967). The material consists of three pairs of plates taken with the 30-cm refractor (f = 5·1 m) of Bonn Observatory with epoch differences of 40 to 43 years. The cluster IC4996 contains no yellow giants. Van Schewick (1967) has also determined the proper motion of NGC2307 from measurements at Groningen and Bonn. The cluster contains no yellow giants. New fundamental proper motions on the FK4 system, with standard errors between $\pm 0\overset{''}{.}002$ and $\pm 0\overset{''}{.}004$ per annum, have been determined by Tucker and Blackwell for 19 members of Praesepe, from data in the G.C. supplemented by modern observations. The mean proper motion of the cluster is:

$$15\ \mu_\alpha \cos\delta = -0\overset{''}{.}0355$$
$$\mu_\delta = -0\overset{''}{.}0164 \pm 0{\cdot}0007 \quad \text{(s.e.)}.$$

Murray (1968) has completed his proper motion study of the region of M 67 (NGC2682). Outlying red-giant members have been found up to about 0°5 from the cluster centre. The main sequence of

https://doi.org/10.1017/S0251107X00024007 Published online by Cambridge University Press

the outlying cluster members shows the marked gap below the turn-off point, which is well-known for the stars in the central region.

Cannon (1968 and in press) has carried out proper motion and photometric studies in NGC188, 752, 6939, 7789, 2420. All five clusters have a clump of red giant stars, which appear to be equivalent to the horizontal branches of globular clusters; comparison with theoretical models by Faulkner and Iben supports this interpretation.

L. S. Koroleva has been putting finishing touches to a proper motion catalogue, containing some 4000 stars in the open clusters NGC6866 and NGC7789.

Miscellaneous studies of open clusters

At the Vatican Observatory two-colour photometry on IC4665 has been published by McCarthy and O'Sullivan (1969) who used 6 plates exposed in the blue and 6 in yellow wavelengths. Standard plate-filter combinations were employed and the photoelectric standards of Hogg and Kron and those of Johnson plus an extension to fainter magnitudes by the photoelectric photometry of McCarthy and of Coyne provided the basis for photographic interpolation. All stars selected for proper-motion studies by Vasilyevskis were observed and colour-magnitude diagrams constructed for the "probable" and "possible" members as defined by the proper-motion measures. Both diagrams indicate the presence of late type stars in the subgiant domain and a gap of 0·3 magnitude near $B-V=+1{\cdot}0$. Abt and Snowden have concluded that there is no extension of the main sequence of this cluster beyond $V=12{\cdot}0$.

In continuation of their work on the Pleiades cluster McCarthy and Treanor (1968) have published a Finding List of 144 possible candidates as late-type low-luminosity members of this cluster. This listing has been made from all available material and considers flare activity, photometric properties, proper-motion data, luminosity criteria and Hα-emission features, which have been observed for each star. Finding charts are provided for 120 stars which could be securely identified. McCarthy has completed a study of 22 of the late-type stars detected in the original Vatican objective-prism study. All 22 stars proved to be late-type dwarfs.

Pik-Sin The is studying Tr 27, Tr 28, NGC6416, NGC6425 in collaboration with N. Stokes. The distances obtained so far for these clusters are 1050 pc, 1470 pc, 800 pc, 840 pc. The data indicate that Tr 27 and Tr 28 are located in the Sagittarius spiral arm (as delineated by optical spiral tracers), while NGC6416 and NGC6425 are interarm objects.

T. Lloyd Evans obtained photometric and spectroscopic data in IC2581 (in press). He has found a distance of 2500 pc and age $\sim 10^7$ years. The cluster contains 2 super-giants, an eclipsing binary and a variable Be star. The evolutionary significance of HD90772 (A7 Ia) in the cluster is discussed. In NGC6383 (age 5×10^6 years) he found a number of rapid variables with *UV* excess (possibly T Tauri stars).

In a paper (1968), Lloyd Evans has concluded that the M super-giants in $h+\chi$Per are unlikely to be pre-main sequence objects.

Burkhead at Indiana is determining color-magnitude arrays in NGC609, 2506, 6819, 6939, IC166, Trumpler 5, and King 11; the magnitudes are photographic *UBV* with photoelectric calibration.

Polarimetric observations have been made by K. Serkowski in M67, Praesepe, NGC3680, NGC4755, NGC3532, NGC3766 and M6. The K0 II star BM Scorpii in M6 has a large intrinsic polarization, changing with time.

V. V. Lovdovski is preparing an extensive observational program comprising over 300 open clusters.

The three-colour photometric determination of the distances of galactic clusters was continued at the Astronomical Institute of Basle using mainly plates of the Palomar and Asiago Schmidt Telescopes. The list of clusters treated with methods of three-colour photometry at different observatories comprises now about 230 objects. The spiral structure is well defined by the distribution of young clusters for distances up to 3 to 4 kpcs.

At the Main Astronomical Observatory of the Ukrainian Academy of Science in Golosseyevo, with the Abastumani Observatory also taking part, absorption of light in space in the directions

https://doi.org/10.1017/S0251107X00024007 Published online by Cambridge University Press

Table 3. Globular clusters

NGC	Observer and references	Photometry, method and limiting data			Other data obtained, remarks
104 = 47 Tuc	Royal Greenwich Obs.				c-m, p.m., var
	Serkowski				pol.
288	Philip	*UBV*	pe		sequence in area of NGC288
	Menzies		pe + pg		
362	Philip	4 colours			in progress
	Serkowski				pol.
1261	Alcaino	*UBV*	pe	16·5	
1851	Alcaino (1969)	*UBV*	pe	16·5	
2808	Philip	*UBV*	pe		in area of NGC2808
	Ford, Gascogne			18	c-m 1000 stars
	Alcaino (1969)	*UBV*	pe	16·5	
3201	Philip	4 colours			in progress
4372	Ford, Gascogne			18	c-m 1000 stars
	Alcaino	*UBV*	pe	16·5	
	Andrews		pe + pg	17·5	
4590	Andrews		pe + pg	17	var
4833	Alcaino	*UBV*	pe	16·5	
	Menzies		pe + pg		
5024 = M 53	Panova				
5139 = ω Cen	Dickens, Woolley (1967)	*B, V*	pg	19·5	HR, var
	Serkowski				pol.
5272 = M 3	Serkowski				pol.
5904 = M 5	Simoda, Tamikawa				HR
	Philip	4 colours			in progress
	Serkowski				pol.
	Zhukov				
5927	Menzies			pg + pe	
6121 = M 4	Philip	4 colours			in progress
	Landolt	*UBV*	pe		
6139	Andrews		pe + pg	19	
6171	Dickens	*UBV*	pg		var
6205 = M 13	Simoda, Kimura (1968)				*L*(*M*)
	Simoda, Tamikawa				*L*(*M*)
6266	Ford, Gascogne (1967)	*B, V*			var 50 stars
6341 = M 92	Philip	4 colours			in progress
	Kadla	*UBV*			p.m.
6352	Alcaino	*UBV*	pe	16·5	
	Menzies		pg + pe		
6362	Alcaino (1970)	*UBV*	pe	16·5	
6397	Cannon	*B, V*	pg	19	p.m. 450 stars
6541	Menzies		pe + pg		
6752	Alcaino (1970)	*UBV*	pe	16·5	
6809 = M 55	Philip	4 colours			in progress
	Menzies		pe + pg		
6981	Dickens	*UBV*			c-m, var
7078 = M 15	Panova				
7099	Dickens	*UBV*			c-m
	Andrews		pe + pg	19	
Pal 12	Andrews		pe + pg	18	

Abbreviations to Table 3. c-m = colour-magnitude diagram; p.m. = proper motion; var = variable; pol. = polarization; HR = Hertzsprung-Russell diagram; *L*(*M*) = luminosity function; pg = photographic; pe = photoelectric.

of NGC2129, 6802, 6823, 6834, 6913, 7086, 7654, is estimated by V. I. Voroshylov, L. N. Kolesnik, E. P. Polishtchuk, G. L. Fedorchenko, N. B. Kalandadse *et al.*

Goy studied IC1805 with the Geneva photometric system $UBVB_1B_2V_1G$. He has found that the interstellar extinction law is not the same for all O stars of the cluster. He has shown that the wavelength of the knee of the extinction law at 4300Å is not the same for all the stars.

The 200-inch telescope has been used by S. van den Bergh to obtain the faint photometric *UBV* sequence in NGC7142.

Photoelectric *UBV* photometry of the high-latitude galactic cluster Mel 227 has been obtained by A. Ardeberg. Within a distance of 20′ from the centre 51 stars have been measured. Objective-prism plates with a dispersion of 110Å mm^{-1} are available.

An extended source detected (Price, 1968) recently at 2·2 μ is in excellent positional agreement with a heavily reddened cluster previously found by Westerlund (1961) in Ara. The observed brightness at 2·2 μ may be fully explained by the radiation from the cluster members.

L. Mavridis completed a study of the space distribution of the M, S, C type stars in an area centered at the open cluster NGC752. Similar studies are currently carried out in two areas centered at the open clusters NGC7789 and NGC129 by A. Tsioumis and C. Poulakos, respectively.

GLOBULAR CLUSTERS

Luminosity function

The luminosity function for M13 has been obtained by M. Simoda and H. Kimura (1968) down to the visual magnitude 19, by means of star counts on plates taken with the 74-inch reflector of the Okayama Astrophysical Observatory. Particular attention has been paid to the counting method. A significant deviation has been found between their luminosity function and the M3 luminosity function determined by Sandage. The results for M13 give a generally steeper gradient as compared with Sandage's results for M3.

By use of the new luminosity function and the Population II stellar models given by I. Iben, the life-time and effective helium-core mass have been obtained for each evolutionary stage up to the giant tip. Agreement between the present results and the theoretical ones is good, both for low ($Y_e = 0{\cdot}10$) and high ($Y_e = 0{\cdot}35$) helium cases, contrary to the results obtained by Sandage for M3. The life-time of the horizontal-branch stars have been found to be 9×10^7 years for $X_e = 0{\cdot}9$ and 5×10^7 years for $X_e = 0{\cdot}65$. Some evidence which seems to favor the high helium content is discussed.

Simoda and Tamikawa work also on the luminosity function for M5 and M13, using Kitt Peak and Palomar 200-inch plates for the former and Kitt Peak plates for the latter. Results hitherto obtained suggest a similarity between M5 and M13. The result for M13 seems to be essentially the same as the previous one. Thus, the luminosity function for M5 and M13 seems to agree with that expected from the theory. For M5, a preliminary count down to the fainter magnitudes suggests the mass segregation effect to be consistent with the theory and giving evidence for decreasing original luminosity function with increasing magnitude. The brighter part of the HR diagram for M5 determined by Arp has also been revised, using Arp's standards and plates taken by 84-inch telescope at Kitt Peak Observatory. Results strongly suggest that intrinsic widths of giant, asymptotic, and yellow horizontal branches are all very small.

Wilson and King, at Berkeley, are studying luminosity functions of globular clusters, using dynamical models to extend limited counts to a whole cluster. When treated in this way, M13 and M3 have very similar luminosity functions.

Hartwick at Victoria has determined the luminosity function of M92.

Miscellaneous studies of globular clusters

R. J. Dickens and R. Woolley published (1967) two papers on the structure and dynamics of the cluster NGC5139 (ωCen) and on the Cepheid variables. Photographic B, V photometry down to $V=19\cdot5$ has been obtained. The colour-magnitude diagram of members of NGC104 (47Tuc), selected from a proper-motion study based on plates taken with 24-inch refractor, shows a well defined sequence of stars brighter than, and asymptotic to the giant branch. The RR Lyrae variable HV814 is almost certainly not a member. Dickens has obtained light curves in U, B, V for 22 variables in the metal-rich cluster NGC6171 from plates taken at Mount Wilson. Very good correlations between period, amplitude and colour have been obtained. Analyses have shown a complete separation in colour between a- and c-type variables in marked contrast to the variables in metal-poor clusters such as ωCen. This cluster contains large-amplitude variables with periods $\sim 0\cdot4$ days, which probably represent the cluster counterparts of short-period large-amplitude a-type variables, previously only known to occur in the general field. Dickens has also obtained colour-magnitude and two-colour diagrams for the cluster NGC6981. The horizontal branch occurs at $V=16\cdot9$ with approximately equal populations on each side of the variable gap. Provisional values of the reddening and ultra-violet excess are $E_{B-V}=0\cdot07$ and $\delta(U-B)=0\cdot20$ respectively. Dickens has obtained colour-magnitude and two-colour diagrams for the cluster NGC7099, which appears to be very metal-poor. The horizontal branch occurs at $V=15\cdot5$ and is heavily populated on the blue side of the variable gap. Provisional values of the reddening and ultra-violet excess are $E_{B-V}=0\cdot10$, $\delta(U-B)=0\cdot28$, respectively. Cannon has measured proper motions for about 450 stars with $B\leqslant 15^m$ in the field of NGC6397. Photographic B, V photometry down to $V=19\cdot0$ has also been obtained.

J. W. Menzies is studying globular clusters (the suspected metal-rich clusters, NGC5927, 6352 and the early-spectral-type clusters NGC288, 4833, 6541, 6809) down to below the horizontal branches, in order to study chemical-composition effects on the colour-magnitude diagram. The colour-magnitude diagrams show considerable differences, even among clusters suspected of having the same metal abundance.

A program of four-colour measures of blue horizontal-branch stars in globular clusters has been started by A. G. Davis Philip. Measures of blue horizontal-branch stars in M4, NGC362, and NGC6809 have been already made, and measures are planned in M5, M92, NGC3201. It is hoped that these measures will be of interest for the helium-abundance problem and in defining the relationship between field and globular horizontal-branch stars.

V. Ford and S. C. B. Gascoigne (1967) obtained two-colour light-curves (B and V) for about 50 short-period variables in NGC6266. This cluster shows strong differential absorption, reaching about one magnitude in B. Comparison of colours and magnitudes of variables in the reddened part with those in the unreddened part of the cluster gives a value for A_0/E of 2·9.

K. Serkowski has measured the integrated polarization of globular clusters M3, M5, NGC362, 47Tuc, ωCen. Line-strength estimates in the integrated spectra of 43 galactic globular clusters have been made by S. van den Bergh, using image-tube spectra obtained at the Cassegrain focus of the 200-inch. The purpose of this program was to compare the globular clusters in our own galaxy with those in the Andromeda Nebula. Such a comparison shows that the average metallic-line strength of globular clusters in the Andromeda Nebula is significantly greater than it is in the Galaxy.

Star counts in 54 globular clusters made by J. King, have been published (1968). The results are now being analysed, along with all other data available in the literature, to determine radii of as many clusters as possible. The tidal limiting radii can be determined in more than 40 clusters. The results are also being analyzed for correlations between the various quantities.

At the Geneva Observatory L. Martinet is undertaking a compilation of various data about the known globular clusters (HR diagram, integrated photometry, variables, radial velocity, position, etc.) comparing them with those for other old objects (RR Lyrae, subdwarf, etc.) in order to specify more precisely some physical and dynamical features related to the initial evolution of the Galaxy.

NEW OPEN CLUSTERS AND EXTRAGALACTIC CLUSTERS

Sanduleak and Philip (1968) published spectra and photometry of a new open cluster in the line of sight of the Large Magellanic Cloud. The cluster was confirmed by Murray, Dickens, Walker (1969). The colour-magnitude diagram resembles that of the Hyades. Further astrometric and photometric work on some 600 stars in this region is in progress. The distance modulus calculated for the cluster is $7^m_.8$, which when corrected for $0^m_.2$ of absorption yields a distance of 330 pc to the group. It is 185 pc below the galactic plane.

M. Walker used the McGee Spectracon to obtain direct electronographic images in B and V of globular clusters in the Magellanic Clouds. The intent is to use the existing photometry down to about 19th magnitude for zero point and colour equation, and to continue the c-m diagrams to the limit of the Spectracon. Stars as faint as $V = 22{\cdot}6$ and $B = 23{\cdot}2$ have been measured. The following clusters were observed at Tololo with Spectracon, in SMC: Kron 3, NGC121, 339, 361, 419, 458; in LMC: NGC1783, 1866, 2004, 2164, 2209, 2231, 2257, Hodge 11.

Photoelectric *UBV* observations were made by G. A. H. Walker (1968) for stars in the associations Anon b4 and NGC2081 in the Large Magellanic Cloud.

OPEN STAR CLUSTERS AND SPIRAL STRUCTURES

(Prepared by W. Becker)

Since 1967 the number of galactic open star clusters observed in three colours has increased to about 216 objects. Ninety of them are young enough to demonstrate the spiral structure of our Galaxy. They have confirmed and improved the existing picture of the space distribution. But in certain directions gaps exist, which require new observations. This is particularly the case between the galactic longitudes $l^{II} = 290°$ and 330° and between 35° and 65°. These observations should help to decide upon two questions of interest. First, one can expect from such observations the answer to the question whether a continuous spiral arm exists, going from Carina over Sagittarius to Scutum, or whether there is a gap near $l^{II} = 320°$, indicating that the Carina arm extends in the direction of the Sun and continues in the direction of Cygnus. The second question refers to the new results presented by Weaver at the Basel symposium, according to which the so-called local spiral arm is in fact not a real spiral arm but only a spiral-arm-like feature, emerging in the direction $l^{II} = 50°$ from a Carina-Sagittarius-Scutum arm and fading out in the direction of Puppis. In this way the large pitch angle of 21° of this local feature becomes understandable.

In the future the photometric observations will be extended to fainter objects, in distances up to 5 kpc, in which the photometric method will give results reliable enough for detecting spiral structure.

New spiral arms may be detected in this way, spiral arms which are indicated up to now only by a few objects (clusters and H II regions).

A detailed study of the space distribution of clusters of different ages has not been made up to now. It may well be that the number of clusters in the critical age of 50 to 100×10^6 years is yet too small.

CLUSTERS AND STELLAR EVOLUTION

(Prepared by G. Larsson-Leander)

The star clusters are important tools for testing theoretical computations of stellar evolution. Detailed comparisons between theory and observations were made by Iben (1967). Considering the young clusters, Iben suggested that the red super-giants of h and χPer might be stars in pre-main-sequence contraction. Schild (1967) segregated various groups of stars formed at different times, and according to his interpretation the red super-giants are highly evolved objects. Walker (1969) has recently investigated the stars in the vicinity of the Orion Nebula. No evidence for subgroups of different ages were found. The gravitationally contracting stars tend to lie closer to the main sequence than predicted by theory.

Statistical studies of the distribution of red and yellow giants in the colour-magnitude diagrams for groups of several clusters of medium age, and comparisons with theoretical evolutionary tracks were made by Lindoff (1968) and by Barbaro, Dallaporta and Fabris (1969). Lindoff found the giants situated too low, as compared with the theoretical tracks, which would indicate substantial mass loss, while Barbaro *et al.* found smaller discrepancies. As shown by Barbaro *et al.* the dissimilar results are partly due to the different bolometric and colour corrections used in the two studies.

Meyer-Hofmeister (1969) computed a theoretical HR diagram to fit the Large Magellanic Cloud cluster NGC1866. Similar computations by Schlesinger (1969) has produced theoretical colour-magnitude diagrams for clusters of ages between $22{\cdot}5 \times 10^6$ years and 4×10^9 years. Comparisons were made with several clusters, including M11 and M41. The agreement between theory and observations was on the whole found satisfactory. It is stressed by Schlesinger that to make the comparisons really convincing, spectral types should be determined for the brighter cluster stars and careful membership studies should be made for clusters with published colour-magnitude diagrams.

The colour-magnitude diagrams of older Population I clusters, like M67 and NGC188 exhibit gaps just off the main sequence. The gaps are caused by the rapid evolution of stars with convective cores during the phase of central hydrogen exhaustion. The size and position of the gaps may be used for determining chemical composition and age, but the results are highly dependent upon the opacity law assumed. This is shown by Demarque and Schlesinger (1969) and by Aizenman, Demarque and Miller (1969) discussing the gaps in NGC188 and in M67 and NGC188, respectively. The most consistent results for M67 are obtained for the range of $Y = 0{\cdot}38$–$0{\cdot}32$, corresponding to $Z = 0{\cdot}03$–$0{\cdot}04$, which would lead to the surprisingly low age of about 3×10^9 years.

The colour-magnitude diagrams of the globular clusters were interpreted by Iben and Faulkner (1968) in terms of metal-poor stars with high helium abundance ($Y \approx 0{\cdot}33$). On this interpretation the giants and the horizontal-branch stars, evolving towards higher effective temperature, have essentially the same mass (about $0{\cdot}8\ M_\odot$) and the cluster ages are about 9×10^9 years. The relevant arguments were elaborated upon by Rood and Iben (1968). They also showed that neutrino losses would reduce the helium abundance to $Y \approx 0{\cdot}30$ and the cluster ages to about 8×10^9 years.

On the other hand, theoretical studies of the RR Lyrae pulsations by Christy (1968), demand masses of about $0{\cdot}5\ M_\odot$. Spectrographic and narrow-band photoelectric observations by Newell, Rodgers, and Searle (1969) of horizontal-branch stars in NGC6397 corroborate this, in yielding a mean mass of $0{\cdot}55\ M_\odot$. According to Christy's models there is a correlation between the blue-boundary colour of the RR Lyrae instability strip and the helium abundance. This was used by Sandage (1969) in a discussion of new photometry of M3, M13, M15, and M92. A mean helium abundance of $Y = 0{\cdot}32$ was found, and Sandage states that within observational errors Y is the same for M3, M15 and M92, despite large differences in metal abundances.

Considerable evidence has thus accumulated to the effect that the helium abundance of old Population II stars is in agreement with the theory of the primordial fire-ball. If the masses of the horizontal-branch stars are in the interval $0{\cdot}5$–$0{\cdot}6\ M_\odot$ it seems necessary to postulate substantial mass loss subsequent to the giant phase. Otherwise the ages of globular clusters will considerably surpass the Hubble age of the universe.

YOUNG CLUSTERS

(Prepared by M. Walker)

These objects overlap somewhat with associations; in this report, I shall discuss only investigations of clusters since the associations will undoubtedly be discussed elsewhere. In conformity with the guide-lines for the preparation of the current Draft Report, I list here only those programs or results that appear to me to be of particular significance.

I believe that the most important observational discoveries are those of Becklin and Neugebauer (1967) of an infrared star in the Orion nebula, having a black body temperature of 700K and perhaps representing a very early stage of stellar evolution, and by Kleinman and Low (1967) of an infrared nebula, 20″ from the above-mentioned infrared stellar object, having a diameter of $> 30''$ which they interpret as an interstellar cloud of mass $\sim 10^2$–$10^3\ M_\odot$ at a temperature of 70K which is just beginning to contract into stars. That star formation does occur in condensations having masses of this size has been discussed by Aveni and Hunter who cite as examples the BM And, IC 348,

https://doi.org/10.1017/S0251107X00024007 Published online by Cambridge University Press

NGC7129, and NGC7023 groups, each of which have masses $\leqslant 200 M_\odot$. A related discovery of importance is the finding by Raimond and Eliasson (1967) of an OH-emission source in the Orion nebula that apparently coincides in position with the infrared stellar object found by Becklin and Neugebauer. These observations emphasize the fact that we now have, with the development of radio and far infra-red detectors, the observational means to observe objects at the very beginning of their evolutionary history when their temperatures are still so low that they have been undetectable by methods heretofore available. Further observations in these wavelength regions are clearly of prime importance.

Other information on the earliest stages of stellar evolution may be provided by the work of Penston (1969) who has studied the distribution of matter in the Bok globules in the Orion nebula. From the variation of optical depth with projected radius, the masses of the globules are found to be of the order of 1 $M_\odot$ and their temperatures about 10K.

Reddish (1967) finds that the increase in interstellar reddening with increasing luminosity first described by Blanco and Williams (1959) occurs in all clusters and associations having stars brighter than $M_v = -9$ (ages $< 10^5$ years). He concludes that very young, early-type stars are surrounded by obscuring clouds having diameters 1 pc, and masses $\sim 30\ M_\odot$.

It is becoming increasingly clear that in order to understand the early stages of stellar evolution that we observe in the young clusters, observations of the c-m diagrams of the clusters are not enough. Detailed spectroscopic observations of the individual stars are also needed. Thus, the photometric study of stars in the Orion nebula cluster by Walker (1969) is of interest since it provides *UBV* data for stars down to $V = 18$, from which objects for spectroscopic or further photometric study can be selected. This study indicates that stars redder than $(B-V)_0 = -0{\cdot}09$ are still in the gravitational contraction stage, corresponding to an age of 3×10^6 years, and that there is, from the *UBV* data, no evidence for an abnormal reddening law in the Orion nebula.

Williams and Cremin (1969), using theoretical evolutionary tracks, have extended the work of Iben and Talbot (1966) and have concluded that there is strong evidence for a definite spread in the ages of the stars in NGC2264, NGC6530, IC2602, and IC5146. This interpretation depends, however, on the assumption that T_e can be obtained directly from the observed $(B-V)$, and thus hinges on the correct explanation of "Walker's anomaly" – the fact that many of the intrinsically faint stars lie close to or even below the main-sequence. As indicated above, spectroscopic observations will be required to investigate this question. Evidence for a spread in the ages of the stars in IC2602 has also been found by Hill and Perry (1969) from the discordance between the nuclear age of the brightest star and the contraction age.

The gravitationally contracting stars in IC1805 have probably been detected by Ishida (1969) who has obtained *UBV* observations of 54 stars of $V \leqslant 14$ that have probabilities of cluster membership 0·5 according to the proper-motion study by Vasilevskis, Sanders, and van Altena (1965). Ishida finds that the stars redder than $(B-V)_0 = 0{\cdot}2$ lie above the main-sequence, corresponding to an age of 1×10^6 years. The cluster is irregularly reddened, and spectroscopic observations are needed to establish membership and reddening of the individual stars.

Schild (1967) has studied the ages of stars in h and χ Per, finding differences in the ages and distances of the two clusters, while Slettebak (1968) has studied the spectral types and rotational velocities of 83 stars in h and χ Per, and finds that the rotational velocities of the giants in the clusters are greater than for field stars of the same types.

DYNAMICAL MODELS AND NUMERICAL COMPUTATIONS

(Prepared by P.-B. Bouvier)

King is preparing for publication dynamical models of globular clusters, based on a realistic luminosity function. These will include models made specifically to fit the best observed clusters.

Prata has extended King's models to a calculation of dynamical evolution, including the effects of the galactic tidal force, the escape of stars, the loss of mass through stellar evolution as well as the energy input and star-loss induced by gravitational shocks due to passing interstellar gas clouds.

Results include a specific study of M 67, showing that the original mass function must have differed from the Salpeter birth function. A more general study shows how initial factors affect dynamical evolution and which clusters are most able to survive. As a by-product, it appears that anisotropy is removed from open clusters by the combined effect of galactic tidal forces and internal relaxation.

Hénon (1970) is studing the dynamical evolution of star clusters by a Monte Carlo technique, which is much faster than the exact *N*-body integration. A number of cases with 1000 bodies have been computed. Among other results, it is found that a cluster develops a very dense core and an extended halo; ultimately, almost all the energy is in the core, while almost all the mass is in the halo. Hénon has generalized a previous theoretical computation of the escape rate from an isolated cluster to the case of an arbitrary mass distribution (1969), the rate of escape of energy has also been computed. These escape rates have been confirmed by the numerical integrations performed by Wielen for 11 cluster models each containing 100 stars; some of the models take into account the galactic field, different stellar masses and a mass loss of evolving stars, in order to allow a direct comparison with open clusters.

These models indicate that the observed age distribution of open clusters can be explained as caused by a dynamical dissolution of open clusters due to star escape. Work on computer simulation of star clusters and clusters of galaxies was continued by Aarseth. Since the Paris colloquium (1967), three more cases of the 250-body problem, including different mass spectra, have been integrated for longer times. Special attention was drawn towards the influence of binary stars on the escape rate and the disruption of the cluster. A description of a perturbation method as applied to the *N*-body problem will be given in a forthcoming paper.

Hayli investigated the influence of the tidal galactic field on the evaporation of stars from an open cluster.

Bouvier and Janin, who had also taken part in the collective attack on the 25-body problem at the 1967 Paris meeting, examined later the disruptive influence of interstellar gas clouds passing near a star cluster; this led to an extension of Janin's numerical program for the *N*-body problem. Investigating also the early evolution of self gravitating systems, Bouvier and Janin dealt with the problem of the waterbag model for a spherical system. The waterbag model for a system of parallel plane sheets is also being reexamined by Janin with a more efficient numerical method, in order to test some former results obtained by Lecar and by Hohl and Feix.

U. Veltmann has discussed the system of globular clusters in the Galaxy, evaluating the possibilities of determining from observations its spatio-kinematical properties, in order to see to what extent they agree with the theory of stellar hydrodynamics.

Spitzer has shown that in a mixture of two stellar masses equipartition becomes impossible if the total mass of the heavier stars exceeds a critical value.

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President of the Commission