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27*a*. SOUS-COMMISSION DE CO-ORDINATION DES RECHERCHES GALACTIQUES (ETOILES VARIABLES)

MEMBRES: Baade†, Blaauw, Kukarkin, Oosterhoff.

Sub-Commission *27a*, like Sub-Commission *33a*, is primarily concerned with special problems. It has not had occasion to meet and has nothing to report. Adequate reference to work done in the field of variable stars in Galactic Research is made in the report of the main Commission.

27*b*. SOUS-COMMISSION DES ETOILES VARIABLES DANS LES AMAS

PRÉSIDENT: Mrs Dr. H. B. Sawyer Hogg, David Dunlap Observatory, Richmond Hill, Ontario, Canada.

MEMBRES: Arp, Detre, Kholopov, Rosino, Wesselink.

INTRODUCTION

In this, the second report of this Sub-Commission, the researches now in progress or published since the 1958 meeting will be considered under the following sections: 1. Variables in globular clusters. 2. Variables in galactic clusters and associations. 3. Variables in star clusters of external galaxies. 4. Proposals.

1. VARIABLES IN GLOBULAR CLUSTERS

(*a*). *Discovery of new variables and derivation of periods.* The number of clusters searched has increased to more than 80, with 121 clusters now catalogued as globular. There are now 1576 published variables in 69 clusters. (The last catalogue by Sawyer (**1**) in 1955 contains 1421). In addition five other clusters searched have no variables. One of these is NGC 4372 in which H. Wilkens at La Plata reports he has been unable to find any of the unpublished variables after searching 39 good plates.

A substantial part of the increase in new variables and periods is due to investigations of the rich clusters NGC 6715 (with 82 variables) by Rosino and Nobili (**2**), and NGC 4590 and NGC 6266 (with 83) by van Agt and Oosterhoff (**3**). Clusters containing variables with newly determined periods also include NGC 4147 and NGC 7006 by Mannino (**4, 5**), NGC 6426 by Grubissich (**6**), and NGC 7078 by Notni and Oleak (**7**), in which a new long-period Cepheid is determined. Variables have been found in the intergalactic clusters Abell no. 3 and no. 4 by Burbidge and Sandage (**8**) and in Abell no. 13 by Rosino (**9**), who also worked on Abell no. 4.

Table 1 lists some of the clusters in which investigations are currently being carried out, and supplements a similar table published in the Sub-Commission report for 1958.

Table 1. Globular Clusters under Current Investigation

NGC		NGC	
47 Tuc	Arp (slow variables)	6341	Detre and Lovas (period changes)
3201	Wilkens (5 new)	6402	Sawyer
5024	Wachmann (period changes), Perova	6558	Asiago
5139	Arp (slow variables)	6569	Asiago
5272	Kukarkin and Kukarkina (2 new variables)	6637	Asiago
		6681	Asiago
	Detre and Lovas (period changes)	6712	Rosino and Nobili, periods and new variables
	Arp (slow variables)	6715	Radcliffe-Asiago
5824	Rosino (27 new variables)	6809	Wilkens
5904	Detre and Lovas (period changes)	6838	Sawyer
	Sternberg, Arp (slow variables)	6864	Radcliffe-Asiago
5986	Radcliffe-Asiago (5 new variables, one $P > 1^d$)	6934	Sawyer
		7078	Asiago (period changes and colors)
6121	Sternberg, Wilkens		Detre and Lovas (period changes)
6171	Kukarkin	7089	Sternberg
6205	Arp (slow variables)	7492	Asiago
6273	Rosino, Sawyer		
6304	Rosino (9 new variables)		

The clusters Abell nos. 1, 9, 10, 11, 12 and Shakhbazian's cluster are also on the observing list at Asiago.

The discovery by Feast, Thackeray and Wesselink (**10**) of RR Lyrae variables in 47 Tucanae, long cited as an important example of a cluster lacking them, is worthy of special note. Three-color work by O. J. Eggen, in press, contributes further to our understanding of this cluster.

(*b*). *Period changes.* Several clusters have been studied, including the rich M 3 by Osváth (**11**). In NGC 6121 Wilkens (unpublished) finds only one RR Lyrae star of constant period over the interval 1899–1957. Most extensively studied has been M 15 by Izsak (**12**), Nobili (**13**), Mannino (**14**) and Bronkalla (**15**). Kukarkin and Kukarkina (**16**) have published photographic magnitudes for 81 stars in the outer parts of M 3 preparatory to a study of light changes of the variables.

(*c*). *Miscellaneous correlations.* The period-amplitude relation for RR Lyrae variables has been investigated by Kurockin (**17**). Sandage (**18**) from work in M 3 notes that the period-color relation for RR Lyrae stars may be non-unique. Detre at Konkoly, in co-operation with the Mathematical Institute of the Hungarian Academy, is considering the problem of the general theory of the influence of random fluctuations of the period on the structure of the O−C diagram, a problem studied empirically by Woerkom.

(*d*). *Spectra of globular cluster variables.* Feast and Thackeray (**19**) have obtained spectra (and luminosity classifications) and velocities for some of the red variables in 47 Tuc. Thackeray (in press) has found the spectrum of Var. no. 29 in ω Cen to be that of a typical W Vir star with emission lines. An analysis of light, color and velocity for Var. no. 42 in M 5 has been published by Wallerstein (**20**).

(*e*). *Variables surrounding globular clusters.* Kukarkin (**21**) has investigated five in the neighborhood of NGC 5466, while Kurockin (**22**) has shown an excess of RR Lyrae stars in the neighborhood of M 3 and five other clusters, which he interprets as dissipation from the clusters.

(*f*). *Distribution of variables for determination of cluster diameters or densities.* Earlier work by van den Bergh (**23**) has been more fully pursued by Kholopov (**24**) in five clusters, and Wilkens (**25**).

(*g*). *Absolute magnitude of the RR Lyrae variables.* Evidence is increasing that the mean magnitudes of these variables are not as bright as absolute magnitude zero. Eggen, in a paper in press on 'Three-Colour Photometry of Red Variables' derives a visual luminosity of the RR Lyrae variables as follows: $M_v = +0{\cdot}7$ in ω Cen and $+1{\cdot}0$ in M 80 and 47 Tuc.

(*h*). *Revision of RR Lyrae periods in the galactic center region.* This has an important bearing on the problem of period frequency in globular clusters, especially as the clusters NGC 6522 and 6528 are in the galactic center region. Work by Pavlovskaya (**26**) and Alexander (**27**) shows a more usual distribution of RR Lyrae periods than that obtained earlier by S. Gaposchkin. Photo-electric measures by Ponsen from Leiden at the Radcliffe Observatory on faint variables near the center may help in establishing the distance to the center.

2. VARIABLES IN GALACTIC CLUSTERS AND ASSOCIATIONS

A comprehensive catalogue of 217 variables of almost all types within one cluster diameter, in 80 clusters, has been compiled by P. N. Kholopov (**28**). This catalogue does not attempt to list the numerous RW Aur stars. Except for this catalogue however, investigators of galactic clusters generally appear to be seeking and working on specific types of variables. Accordingly the material on galactic cluster variables in this report will be arranged under types.

(*a*). *Cepheids in galactic clusters.* This important field which 'broke' just before the 1958 IAU meeting has been eagerly pursued. The data available up to that time have been summarized by J. B. Irwin (**29**), who is continuing his own work on southern Cepheids including those in M 25 and NGC 6087. Continuing the determination of precisely known luminosities and colors, Arp, Sandage and Stephens (**30**) have investigated DL Cas in NGC 129, an 8-day Cepheid with a mean absolute magnitude $M_v = -3{\cdot}62$ and $M_b = -2{\cdot}91$, and Arp (**31**) has studied CV Mon, a member of an anonymous cluster. In the same paper Arp shows that AO CMa and XZ CMa are not members of their associated clusters, but that Brun's variable near NGC 2355 is probably a member of it. The investigations by Sandage (**32**) of U Sgr, $P = 6{\cdot}7$ days, in M 25, yield absolute magnitudes at mean light of $M_{V_0} = -3{\cdot}46$ and $M_{B_0} = -2{\cdot}87$. Tifft (**33**) shows that CG Cas is less than one cluster diameter from an anonymous cluster, while within two diameters are BY Cas (NGC 663) and DF Cas (NGC 1027). Fernie, Hiltner and Kraft (**34**) find AQ Puppis a probable member of the association II Puppis.

(*b*). *Eclipsing variables in galactic clusters.* Besides the afore-mentioned compilation of Kholopov, which includes many eclipsing stars, an independent search was conducted by Kraft and Landolt (**35**). It yielded 26 eclipsing stars in the regions of galactic clusters and 577 in the optical regions of associations. Probabilities indicate that many of these are actual members. In a search for W UMa stars in galactic clusters Sahade and Frieboes (**36**) list 16 such stars as possible members of six different clusters, including Praesepe and Coma. Of theoretical importance is the fact that W UMa stars are present in clusters with ages of the order of 10^8 years. Eggen has photo-electric observations of the eclipsing star V 701 Sco in NGC 6383.

(*c*). *Miscellaneous variables.* Mavridis (**37**) has been systematically searching for M-, S-, and C-type stars in the areas of seven galactic clusters, NGC 129, 7790, M 25, and four old clusters, NGC 188, 752, 7789 and M 11. It is well known that a high percentage of stars of these types are variable. In NGC 7789 Mavridis (**38**) notes that the Mira type star WY Cas (Se) is a probable member, while the carbon star BD + 56° 3126 is probably variable. In NGC 6940 Walker (**39**) has a semi-regular variable, period 80 days. Eggen has photo-electric observations of the semi-regular variable BM Sco in NGC 6504. Arp says it is not yet determined whether the long-period variable T Ser is a member of NGC 6633. O'Connell reports that McCarthy with photographic photometry finds variations in the faintest stars in IC 4665. Reddish (**40**) has hunted for small-amplitude variables in NGC 7789, finding one definite and four suspected, though Argue (**41**) had earlier raised a problem of systematic errors in similar work. Detre intends to search for Mira variables around galactic clusters using the Palomar Sky Atlas.

In the region of M 67 a new variable with a super-short period, $P = 0{\cdot}073186$ days, has been found by Kurockin (**42**).

The Pleiades continue to be studied for variability. Sharov (**43**) finds no definite variability from observational data of the last 70–80 years except for Pleione. The light and spectrum changes of Pleione have been studied by Botsula and Sharov (**44**) who have also made photo-electric observations at Engelhardt of stars brighter than $8^m{\cdot}2$ in Praesepe, Pleiades, I Lac and Zeta Per, and find no light changes greater than 0·02—0·03 magnitudes about a mean value. One of the faintest Pleiades is suspected of variation by Dokutchajeva (**45**). In their photo-electric work on the Pleiades, Johnson and Mitchell (**46**) observed a flare of one Pleiades star, and note five other faint stars in the cluster which may be flare stars. They suggest that flare activity may be connected with the process of gravitational contraction of young late-type stars.

(*d*). *RW Aurigae and T Tauri variables.* The great numbers of these stars found in many large areas of the sky make it difficult to summarise progress since 1958. The members of this Sub-Commission feel that to prepare a catalogue of these stars would be a very difficult task. Kholopov notes that any such catalogue must be accompanied by prints or maps showing stars to magnitudes 18 or 19. He himself maintains a card catalogue of all known stars of these types, and has recently published a new classification of objects belonging to the T-associations, according to proposals developed by G. Haro, G. Herbig, and himself (**47**).

As a substitute for such a catalogue, G. H. Herbig has provided for this report a convenient table, with references, listing the main areas in which these stars occur, with a descriptive account of their problems. Over 500 Hα stars, 270 T Tauri stars, and 50 RW Aur stars may be found in the sources listed in Herbig's report, which is appended.

Kholopov has considered the properties of T-associations as a whole (**48**) and given spectrum-luminosity diagrams for a number of T-associations (**49**). He has also reported on the work of other Soviet astronomers. In the Orion-nebula cluster, from infra-red magnitude work Tolskaia (**50**) shows most of the stars to be variable, while in the H II region around the

Lambda Orionis cluster Manova (51) has found 30 new Hα stars, many of which are variable. At Abastumani Dolidze (52) is making an Hα survey in a number of sky regions, and with Arakelian (53) he has found 80 new faint members of a T-association in Rho Ophiuchi. Uranova (54) has investigated the S Mon cluster.

Report on Irregular Variable Stars in Young Clusters and Associations

by G. H. Herbig (Lick Observatory, University of California)

The irregular variable stars that have been found in recent years in young clusters and associations are detectable either by direct photometric search or indirectly, by a spectroscopic search for stars with the Hα line in emission. Each method has its advantages and limitations: a survey for variability must be very extensive in order to screen out extraneous variable stars of other types, and in order to detect variables showing only sporadic activity. On the other hand, although all emission-line stars of the T Tauri variety are probably variable in light, the converse is not true: the spectroscopic survey will miss many nebular variables that show little or no line emission. Furthermore, especially in fields of limited obscuration, the objective-prism survey must be supplemented by slit spectrograms of the blue-violet region in order to weed out background Be stars. For these reasons this compilation of work to date distinguishes between these three kinds of observational material.

It should be pointed out that this Table does not list work in areas of the sky in which the emission-Hα stars may, in the judgement of the writer, be early-type field stars.

Variable-star observations and spectroscopic surveys very probably define the same low-luminosity stellar population *in the associations*, but it is annoying that, outside the associations, the two do not appear to be entirely compatible. The 'T Tauri' and 'T Tauri-like' objects found spectroscopically are only statistically related to the so-called 'RW Aurigae' variables in the general field, the latter being classified as such from their photometric behavior. It is important that one not be misled by this apparent lack of detailed correspondence so as to lose sight of the overwhelming observational fact that in rich, nebulous associations large numbers of irregular variables and emission-line stars are encountered below $M_{pg} = +4$. In this 'Orion population', the 'Orion variables' and emission stars obviously occur in close association; the writer believes that the lack of such a relationship between the 'RW Aurigae variables' and the T Tauri stars arises from the difficulty in identifying, from light-curves alone, the counterparts of the Orion variables in the sky at large.

Clearly, as a group the RW Aurigae variables cannot now be regarded as equivalent to the Orion variables in associations and nebulae. The situation would improve materially if assignment to the 'RW Aurigae class'—if that is the best name for the group—is made very conservatively, and solely on the basis of first-class photometric information. Another desideratum is more detailed data on the light-curves of a sample of Orion variables having a representative spread in characteristics.

Another problem in compiling a list such as this is to know when to stop: is the system of emission-line stars scattered over many square degrees of the Taurus clouds to be considered within the province of this report? Certainly there is no clustering in the usual sense. The view has been taken here that any number of emission-line (but *not* Be) or variable stars associated with a recognizable cluster or bright nebulosity qualifies that system for entry in Table 2. But if no cluster or bright nebula is nearby, I have regarded it as necessary that at least 3 emission objects or variables be known in or near the obscured region.

This Table does not list the individual stars, and gives only the more recent papers in which references to earlier work will be found. A comprehensive list of T associations, many of which

are common to Table 2, has been given by P. Kholopov (43). I have not myself used the term 'T association' in this context, because it hardly seems applicable in cases where a cloud contains a single T Tauri star, although such would be as reasonable an example of the process of star formation as are the very much richer groupings.

Table 2. Investigations of irregular variables in young clusters and associations

Region	α, δ (1900) h m °	Spectroscopic survey (usually at Hα) by:	Slit spectroscopic observations by:	Variable star search or observations by:
C 214	0 00, +68	36	36	—
NGC 225	0 38, +61	34	34	—
IC 1848	2 44, +60	35	—	45
Dark nebula	2 50, +19	35	35	—
NGC 1333	3 23, +31	35	36	—
IC 348	3 38, +32	27	36	27, 65
Taurus-Auriga dark clouds	4^h-5^h, +16° – +30°	16, 35, 40	35, 39, 40	7, 9, 11, 21, 37, 41
NGC 1579	4 24, +35	30	30	—
NGC 1788	5 02, − 3	35	—	—
Dark nebula B30, 31, 32, 225	5 26, +12	3, 16, 35, 40	34, 35, 40	8, 11, 34, 41
Orion Nebula	5 30, − 6	14, 20, 35	12, 20, 25, 58	17, 18, 19, 21, 50, 51, 52, 54, 55
NGC 1977	5 30, − 5			
IC 434	5 36, − 2	15	—	6, 47
NGC 2024	5 37, − 2	—	—	15
Dark nebula B35	5 40, + 9	16, 48	35	10, 53
NGC 2068, 2071	5 42, 0	35	36	35
NGC 2183, 2185	6 06, − 6	35	—	—
NGC 2245, 2247, IC446	6 27, +10	34, 35	—	—
NGC 2264	6 36, +10	22, 28	28	56, 57, 61, 66
Lupus dark clouds	15 40, −35	23	26, 35, 39	1, 49, 68
Scorpio-Ophiuchus dark clouds	16 25, −24	4, 13, 35	35, 59	—
Dark nebula B59	17 05, −27	35	36	—
M 8, M 20, S 188	18 00, −24	31, 60	31	46, 62
M 16	18 13, −14	35	36	63
NGC 6726, 6727, 6729	18 55, −37	22, 24, 35	29, 36, 39	44, 67
NGC 6914	20 21, +42	34	34	—
NGC 7000, IC 5070	20 50, +44	32	32	—
Dark nebula	21 00, +50	35	35	—
NGC 7023	21 01, +68	35, 69	35	35, 65
IC 1396	21 38, +57	5, 38	—	—
IC 5146	21 50, +47	33	—	63
Dark nebula	22 30, +40	34	—	34

The numbers in the last three columns refer to the published observations in the following list.

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3. VARIABLES IN STAR CLUSTERS OF EXTERNAL GALAXIES

At present this field is concerned with clusters associated with the Magellanic Clouds. Variables are being currently studied in six clusters belonging to them. Thackeray (**55**) has found both RR Lyrae type and long-period variables in a study of five stars around NGC 121. In NGC 330 Arp (**56**) has found one variable, probably a Cepheid, as well as a probable Cepheid in NGC 458 (**57**). Wesselink is working on the many variables he discovered in NGC 1466, with new photo-electric observations for precise determination of mean magnitudes, to obtain the distance modulus of the cluster with respect to the Clouds. In NGC 1866 Arp and Sandage (unpublished) have six Cepheids. Alexander (**58**) has investigated NGC 2257, a cluster in which he found 23 variables and Sandage found five. Alexander has determined periods ranging from 0·51 to 0·69 days for six of these stars.

4. PROPOSALS

Detre asks that observatories with globular cluster plates not being used for the study of variables make them available to astronomers interested in the problem. He mentions specifically being handicapped by work published on period changes in M 15 for which the observations are not available.

Detre suggests that more attention be paid to period changes in ω Centauri because this cluster can be resolved to its very center.

Kholopov proposes that since the demarcation between galactic clusters and associations is so hazy, the latter should also be included in the work of this Sub-Commission.

HELEN SAWYER HOGG
President of the Sub-Commission

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