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A study of the spatial stellar mass distribution in some young open clusters

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Summary. The stellar spatial distribution as a function of mass is studied in 11 young open clusters and the presence of mass segregation is observed in seven of these. The possibility of two cluster centres is indicated for NGC 2264. Except in Tr 1, the conventional relaxation and energy equipartition times are larger than the cluster ages which may indicate that the observed mass segregation is due to the star formation processes. However, the possibility of dynamical processes being responsible for the effect of mass segregation in some of these clusters cannot be completely ruled out. Present analysis suggests that observed mass segregation in open clusters older than some million years might be due to a combination of both initial star formation conditions and dynamical evolutionary processes, but in younger ones only initial star formation conditions can be responsible.

1 Introduction

On the question of the spatial distribution of stars in young open clusters, the conclusion of Larson (1982) and Herbst & Miller (1982) that massive stars tend to form near the cluster centre (i.e. an evidence for radial mass segregation) is opposite to the finding of Burki (1978), who finds that massive stars ($M \geqslant 20 M_\odot$) are formed with a lesser degree of central concentration than the less massive stars ($20 > M/M_\odot > 4$). However, if mass segregation observed in open clusters is a reality, then it is important to know whether it is due to dynamical evolution or is an imprint of the star formation processes itself. This question may be better understood by studying young open clusters. Due to the small ages ($\leqslant 5 \times 10^7$ yr) of young open clusters in comparison to their dynamical evolution time ($\sim 10^8$ yr), the spatial distribution of stars in these objects may represent the distribution of stars approximately at the time of star formation. The role of such a study in understanding the formation of the stellar system has been discussed by Mathieu (1983, 1985, 1986). Recently, Mathieu & Latham (1986) studied the spatial distribution of spectroscopic binaries and blue stragglers in the open cluster M67; and McNamara & Sekiguchi (1986) observed mass segregation in M35 and NGC 6530. A description of earlier studies of stellar surface distribution in open clusters can be found elsewhere (*cf.* Mathieu 1985; Scalo 1986).

Furthermore, a knowledge of the spatial stellar mass distribution in open clusters is quite useful for the study of their dynamics. Such studies are generally based on the spatial distribution of stellar brightness which may be justified if cluster members are main sequence (MS) stars. In very young and old open clusters, a good number of stars are respectively in pre-MS and post-MS stage of stellar evolution and for these stars, unlike MS stars, the relation between brightness and mass is not straightforward. Therefore, in these objects the spatial distribution of stellar brightness cannot represent that of stellar mass. Also, before carrying out such studies, a reliable segregation of cluster members from field stars is necessary.

The above discussions indicate that a systematic study of the spatial stellar mass distribution in young open clusters based on reliable cluster members would be desirable. Recently, the required data have been provided in catalogues by Myakutin, Sagar & Joshi (1984, Paper I) and by Muminov (1983) for some young open clusters and the present work uses the opportunity provided by these data to study their spatial stellar mass distribution.

2 Observational data and estimation of stellar mass

We have included 11 young open clusters in the present study. Nine of these namely NGC 581, 654, 2264, 6530, 6611, 6823, 6913, Tr 1 and IC 1805 with membership criteria based on proper motion data are taken from Paper I. For young open clusters, proper motion data provide more dependable membership criteria than others if they can be determined with sufficient accuracy so as to segregate cluster motion from field stars (*cf.* Sagar 1985, 1987a, and references therein). The remaining two clusters (NGC 869 and 884) in the present study are taken from the catalogue of Muminov (1983). In their case the membership is determined on the basis of both proper motion and photometric criteria. The *UBV* data for clusters taken from Paper I are photoelectric and homogeneous while those for NGC 869 and 884 are photographic.

The mass of cluster members is estimated from fitting stellar positions in the HR diagram to modern theoretical models where the effect of mass loss has been considered in the evolution of massive stars ($M \geqslant 20 M_\odot$). The details of the method used for the mass estimation of cluster members taken from Paper I are given elsewhere (Sagar *et al.* 1986, Paper II). The same method has been used to estimate the mass of members in NGC 869 and 884 after constructing their M_V, $(B-V)_0$ and M_V, $(U-B)_0$ diagrams using the distance moduli and interstellar absorption values from Becker & Fenkart (1971). Because of the relatively poor accuracy of photographic photometry in comparison to photoelectric, these masses are accurate to 20–22 per cent, as against 15 per cent in the case of Paper I. However, this accuracy is sufficient for the present work. Because of the presence of a common corona around NGC 869 and 884 and their richness, they are treated differently from others in the subsequent discussion.

Details of the proper motion analysis and relevant information are listed in Table 1. Except for NGC 581 and Tr 1, the accuracy of the proper motion data is generally better than 0.2 arcsec/century which is sufficient for the desired separation of cluster members from field stars. Because of the poor accuracy of proper motion data for NGC 581 and Tr 1, Oja (1965) has been able to separate cluster members only in a very small circular area (diameter 7 arcmin for NGC 581 and 5 arcmin for Tr 1) in comparison to the total area (80×80 arcmin^2) investigated for the analysis.

Generally the area investigated for the separation of cluster members from field stars using proper motion data is rectangular (see Table 1). From this area, the maximum possible circular area has been chosen for the present analysis and the corresponding radius for each cluster is

Table 1. General data for open clusters under investigation. Galactic longitude and latitude are denoted by *l* and *b* respectively. Trumpler class and other informations are taken from Lyngå (1981). In the proper motion details, A and E denote respectively investigated area in arcmin^2 and accuracy in arcsec per century.

IAU Numbers	Sequence number	Other name	l (degree)	b (degree)	Trumpler class	Proper motion details A	E	Source
C0129+604	NGC 581	M103	128.01	-1.75	III2p	80 x 80	0.5	Oja (1965)
C0132+610	Tr 1	-	128.22	-1.13	13p	80 x 80	0.5	Oja (1965)
C0140+616	NGC 654	-	129.09	-0.36	II3m	34 x 32	0.07	Stone (1977)
C0215+569	NGC 869	H Persei	134.62	-3.73	13R	Cricular radius 50	0.2	Muminov (1983)
C0218+568	NGC 884	χ Persei	135.08	-3.60	13R	Circular radius 50	0.2	Muminov (1983)
C0228+612	IC 1805	-	134.73	0.92	III3p	60 x 50	0.16	Vasilevskis, Sanders & Van Altena (1965); Sanders (1972)
C0638+099	NGC 2264	-	202.95	2.21	IV3p	40 x 40	0.1	Vasilevskis, Sanders & Blaz (1965)
C1801-243	NGC 6530	-	6.12	-1.35	II2m	60 x 32	0.06	Van Altena & Jones (1972)
C1816-138	NGC 6611	M16	16.99	0.78	II3m	30 x 30	0.07	Kamp (1974)
C1941+231	NGC 6823	-	59.41	-0.16	13p	30 x 30	0.08	Erickson (1971)
C2022+383	NGC 6913	M29	76.92	0.61	III3p	32 x 30	0.25	Sanders (1973)

Table 2. Radius, completeness limit of the data, age and dynamical relaxation time of clusters under study. M_L is lower limit of mass in solar units to which data are complete. T_E and t are respectively average dynamical relaxation time and age of cluster.

Cluster name	Radius in arcmin Lyngå (1981)	 Presently used	log M_L	log t	log T_E
NGC 581	3	3.5	0.36	6.4	6.7
Tr 1	2	2.4	0.36	7.4	6.7
NGC 654	2.5	16	0.54	7.6	8.0
NGC 869	15	14	0.45	7.1	7.4
NGC 884	15	14	0.45	7.1	7.4
IC 1805	10	25	0.69	5.8	7.8
NGC 2264	15	10*	0.10	7.0	7.4
NGC 6530	7.5	16	0.46	6.3	7.4
NGC 6611	10	15	0.95	6.4	7.9
NGC 6823	6	15	0.90	6.4	7.6
NGC 6913	3.5	15	0.53	6.1	7.0

*Radius around both cluster centres (see text). This value has been used as half mass radius for estimating relaxation time.

listed in the third column of Table 2. The second column gives cluster radii taken from Lyngå's (1984) catalogue. A comparison of the radii used here with those of Lyngå indicates that our cluster area is generally greater than Lyngå's.

Except for NGC 869 and 884, the completeness limit of the data is taken from Paper II. The same method has been used to estimate completeness limits for NGC 869 and 884. These values are listed in the fourth column of Table 2 and indicate that the stars under consideration in all the clusters generally have masses more than 2 $M_\odot$. Stars fainter than the completeness limit have not been used in further analysis because an estimate of the incompleteness factor could not be made for them.

3 Cluster centre

For estimating the radial surface distribution of stars in clusters, it is necessary to fix the cluster centre. We have chosen as cluster centre the point of maximum stellar density in the stellar density versus α and δ plots. An estimate of the centroid of the cluster members' mass indicates that, in general, it differs from the point of maximum stellar density by an arcmin or less which is assumed as the maximum error in locating the cluster centre. Only one cluster centre was observed in all cases except NGC 2264. For this, we obtained two points of maximum stellar density, one near star S Mon (the most massive star in the cluster) and the other near star 115 of Vasilevskis, Sanders & Blaz (1965) which has the highest mass amongst the cluster members located in the immediate vicinity. This is similar to the observed gas, Hα and early-type star distribution in the cluster (*cf.* Mathieu 1986). If cluster members are distributed more or less symmetrically about the cluster centre, as is generally assumed, then in NGC 2264 some members should be located in the area $X=-20$ to 20 arcmin and $Y=23$ to 35 arcmin on the scale of Vasilevskis *et al.* (1965), but not investigated for proper motion data by them.

4 Spatial mass distribution of stars

Cluster members have been divided into three mass groups for NGC 869 and 884, while for others they are divided into only two mass groups. For estimating the radial stellar surface density in any mass group, the cluster region has been divided into 4–20 equally spaced concentric annuli. The stellar surface density, D_i, for the ith zone is defined as

$$D_i = N_i/\pi(R_i^2 - R_{i-1}^2),$$

where N_i is the number of stars in the ith zone, whose outer and inner radii are R_i and R_{i-1} respectively. The width of the zone is chosen such that observed number of stars per annulus in a given mass range is generally four or more. Because of this small number, the study of cluster structure as a function of mass and radius is limited in precision for most of the clusters under study. The dependence of D_i on radius for NGC 581, Tr 1, NGC 654 and IC 1805 is shown in Fig. 1 and for NGC 6530, 6611, 6913 and 6823 in Fig. 2. In NGC 6611 and 6823, such dependence could not be shown for low-mass stars because of the presence of a statistically insignificant number of stars (around 10) in the group.

Because of two centres in NGC 2264 and a common corona around NGC 869 and 884, they are discussed separately.

4.1 NGC 2264

In order to avoid overlapping, only four annuli each of 2.5 arcmin width could be drawn around both the centres. As a result of this only 34 and 26 cluster members are present in concentric

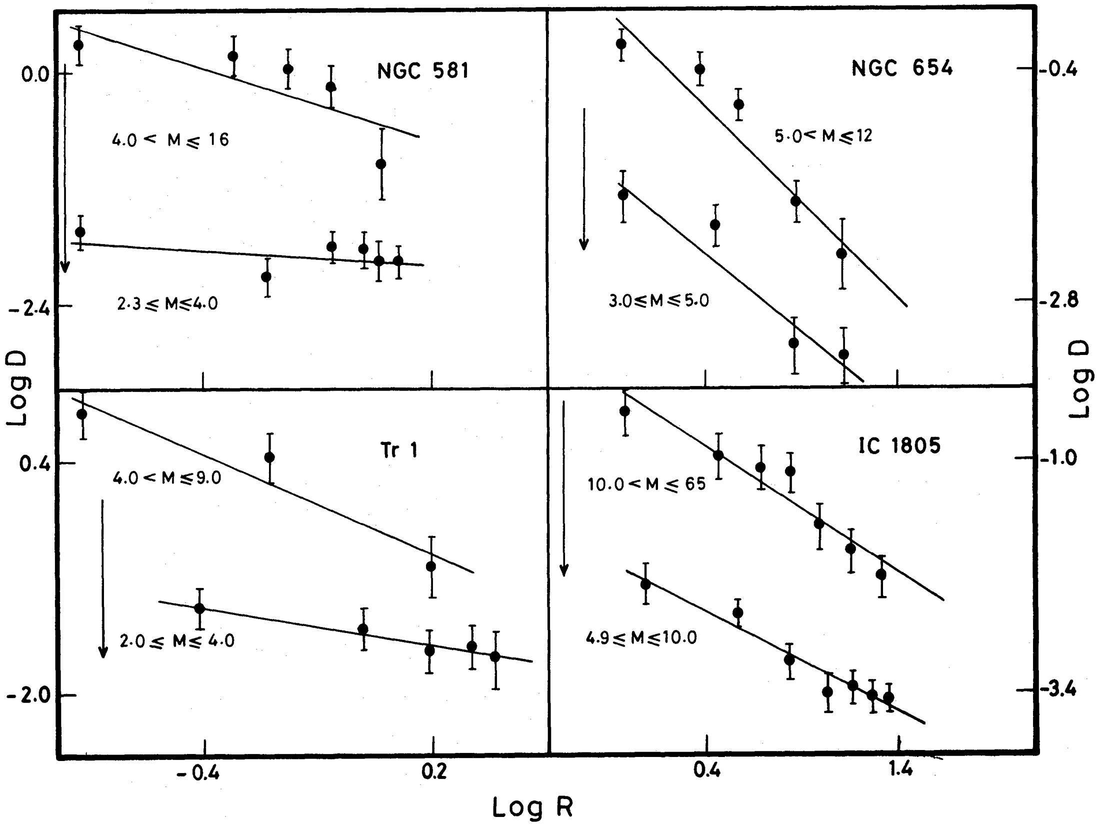

Figure 1. Radial surface density distribution of cluster members in NGC 581, Tr 1, NGC 654 and IC 1805. Continuous line is least square linear fit to the observed points. Length of the bar represents errors due to sampling statistics ($=1/N)^{1/2}$, i.e. the number of stars used in density estimation at that point. The vertical length of arrow denotes the amount in log by which low-mass stars are offset in surface density from the high-mass stars.

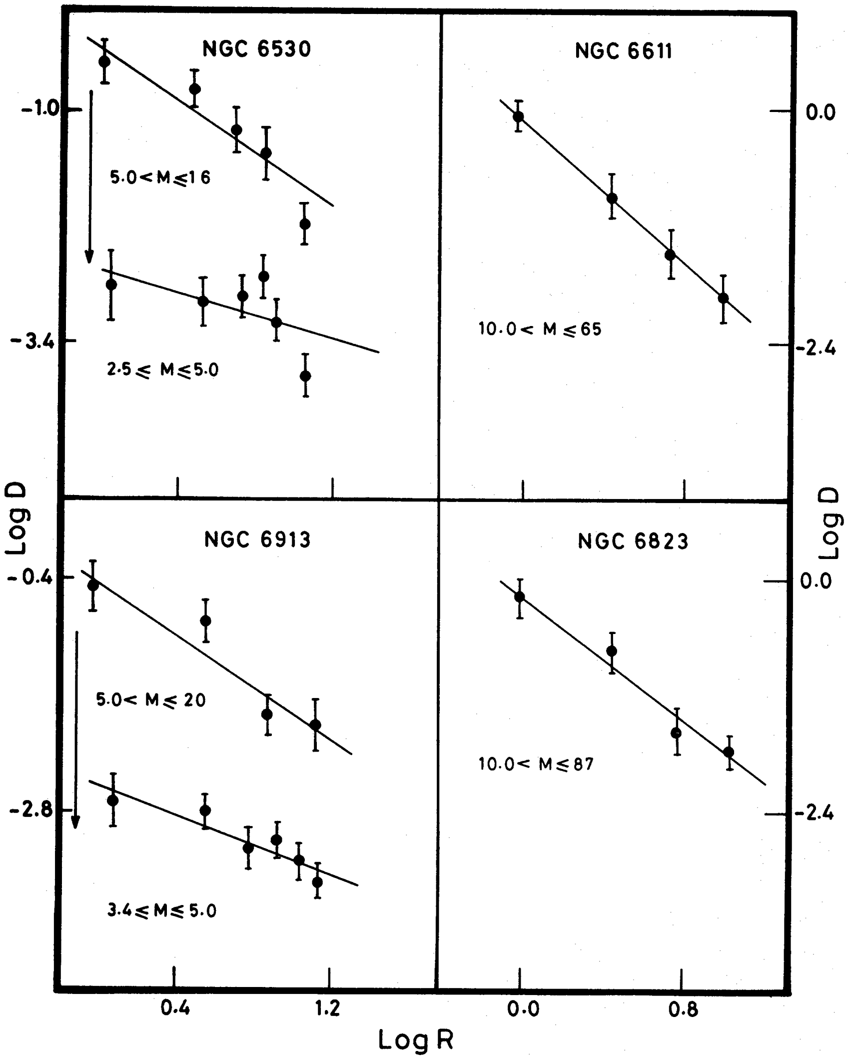

Figure 2. Radial surface density distribution of cluster members in NGC 6530, 6611, 6913 and 6823. Symbols denote the same as in Fig. 1.

circles drawn respectively around S Mon and star number 115. For this cluster, the stars in the mass interval, $1.2 \leq M/M_\odot \leq 3.0$ belong to the low-mass group and stars with $M/M_\odot > 3.0$ form the group of high-mass stars. The presence of a statistically insignificant number of stars in the high-mass group (3 and 10 respectively around star number 115 and S Mon) precludes analysis of radial mass distribution.

4.2 NGC 868 AND 884

The area studied by Muminov (1983) has been divided into three regions namely NGC 869 and 884 regions and the coronal region (i.e. area not covered by the cores of the clusters). The results of radial stellar surface density distribution in these regions are shown in Fig. 3. The low-mass range of the corona contains fewer members and hence has not been considered.

5 Effects of mass segregation on cluster members

Here we study the observed radial stellar surface density distributions of the mass groups; compare the spatial distribution of average mass for all stars with that of the low-mass stars;

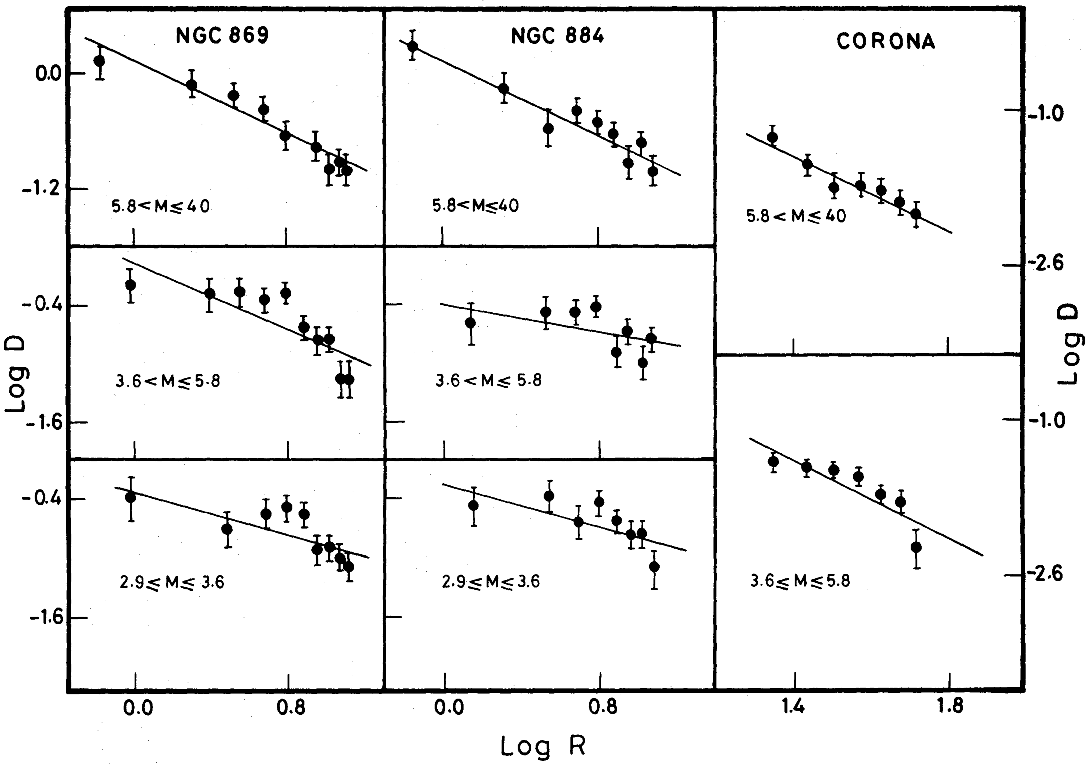

Figure 3. Radial stellar surface density distribution in NGC 869 and 884 and in their common coronal region. Symbols denote the same as in Fig. 1.

estimate the statistical confidence level for the difference observed between the mass groups; and finally analyse the average radii, radial distances of the centre of mass, and median radii of the mass groups. The effects of mass segregation in cluster members have been examined for all the clusters under investigation except NGC 2264, 6611 and 6823, where they could not be studied because of a statistically insignificant number of members in the group of both low-mass and massive stars (see last section). The factors responsible for this are the two centres in NGC 2264 and the completeness limit of present data ($\sim 8\, M_\odot$) in NGC 6611 and 6823.

5.1 OBSERVED RADIAL STELLAR SURFACE DENSITY

In Figs 1–3, one can easily notice the difference between the observed radial surface density distributions of high-mass and low-mass stars. No attempts have been made to fit any theoretical models to the observed radial stellar profiles because they are not applicable for medium and poor open clusters (*cf.* Mathieu 1983, 1985; Terlevich 1987), which is generally the case in the present study (see Table 1). It seems that

$$\log D = a - b \log R, \tag{1}$$

where a and b are the unknown coefficients. In each observed profile of the clusters (Figs 1–3), relation (1) is fitted and coefficients are estimated using least square solutions. The slope b and the absolute value of correlation coefficient r are given in Table 3. As $|r|$ is generally greater than 0.9, assumption of relation (1) may be justified. However, it should be noted that the fitting of relation (1) to the low-mass stars of NGC 581, 869, 884 and 6530 is far from satisfactory. A similar power law (i.e. $D \propto R^{-b}$) has also been observed by Sellgren (1983) for the stars of young clusters namely NGC 2023, 2068 and 7023. This empirical power law can be checked when appropriate theoretical dynamical models for poor and medium young clusters become available.

Table 3. The regression coefficients of the linear relation fitted to the high-mass and low-mass stars of clusters. Slope and correlation coefficient are denoted by *b* and *r* respectively.

Cluster/Region	Regression coefficients for the high-mass stars b	|r|	Low-mass stars b	|r|	Confidence level in % for the difference in slopes
NGC 581	1.30 ± 0.19	0.78	0.29 ± 0.09	0.55	99.9
Tr 1	1.79 ± 0.22	0.96	0.71 ± 0.03	0.97	99.9
NGC 654	2.03 ± 0.26	0.96	1.63 ± 0.28	0.95	70
NGC 869	0.96 ± 0.08	0.96	0.55 ± 0.15	0.77	98
NGC 884	0.97 ± 0.09	0.95	0.53 ± 0.19	0.69	96
CORONA	1.95 ± 0.37	0.97	2.04 ± 0.83	0.86	8
IC 1805	1.32 ± 0.15	0.96	1.04 ± 0.10	0.97	88
NGC 6530	1.36 ± 0.19	0.95	0.61 ± 0.32	0.60	96
NGC 6611	1.78 ± 0.03	0.99	-	-	-
NGC 6823	1.53 ± 0.14	0.98	-	-	-
NGC 6913	1.38 ± 0.17	0.97	0.77 ± 0.12	0.93	99.6

A comparison of the slope of the straight line for massive stars with that for low-mass stars indicates that:

(i) Massive stars in NGC 581, 869, 884, 6530, 6913, IC 1805 and Tr 1 are centrally concentrated relative to the low-mass stars.

(ii) In the case of NGC 654 and common corona around NGC 869 and 884, stellar distributions for both mass groups are more or less similar.

Assuming normal error distributions, statistical significance levels in per cent for the difference in the slopes of low-mass and massive stars are estimated and given in Table 3, which indicates a high level of significance for NGC 581, 869, 884, 6530, 6913, IC 1805 and Tr 1. Medium mass stars differ from the low-mass and massive stars respectively at the significance levels of 83 and 40 per cent for NGC 869, and at 53 and 99 per cent for NGC 884.

5.2 SPATIAL DISTRIBUTION OF THE MEAN STELLAR MASS

Depending upon the size of the cluster and number of members in it, the cluster area is divided into six or eight or 10 equally spaced concentric annuli. For each annulus, average stellar mass (M_{av}) and root mean square (rms) radius are estimated. For NGC 869, 884, 6530 and IC 1805, the variation of M_{av} with rms radius for all stars and for low-mass stars is shown in Fig. 4, for illustration. In NGC 581, 869, 884, 6530, 6913, Tr 1 and IC 1805, the average mass for low-mass stars remains practically constant with radius while that for all cluster members decreases with increase of cluster radius. This observed fact is an evidence for the presence of radial mass segregation in the members of these clusters.

5.3 STATISTICAL TEST

The cumulative radial stellar distributions for the mass groups of IC 1805, NGC 581, 654, 6530, 6913 and Tr 1 are shown in Fig. 5, and of NGC 869 and 884 in Fig. 6. In these figures, mass

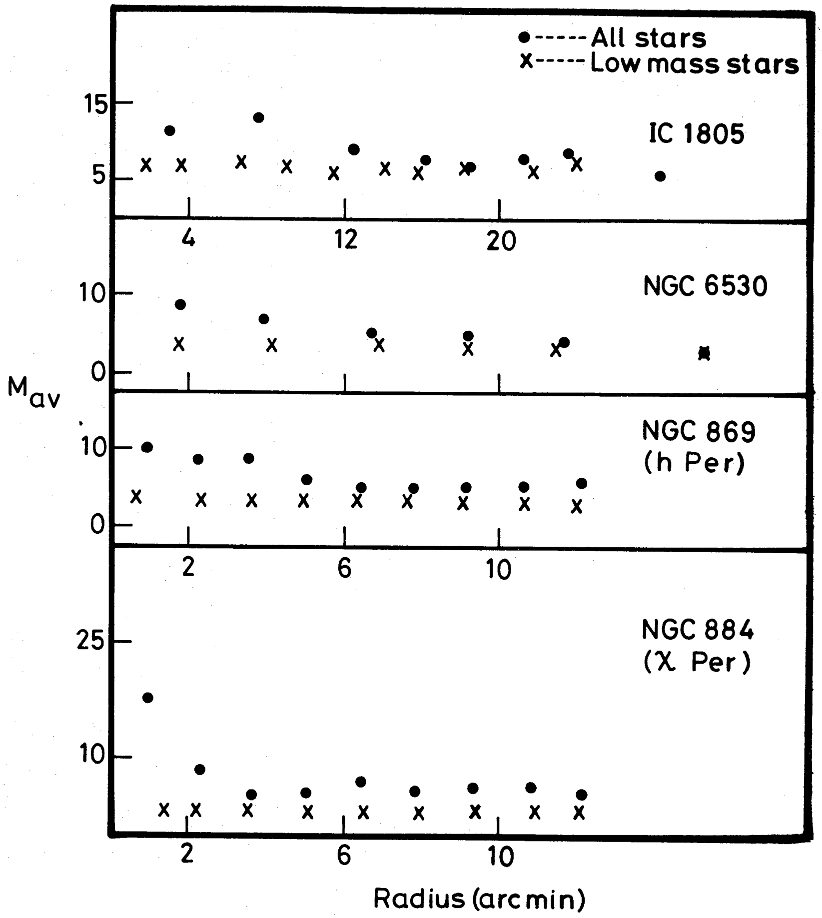

Figure 4. Variation of mean stellar mass with rms radius in NGC 884, 869, 6530 and IC 1805.

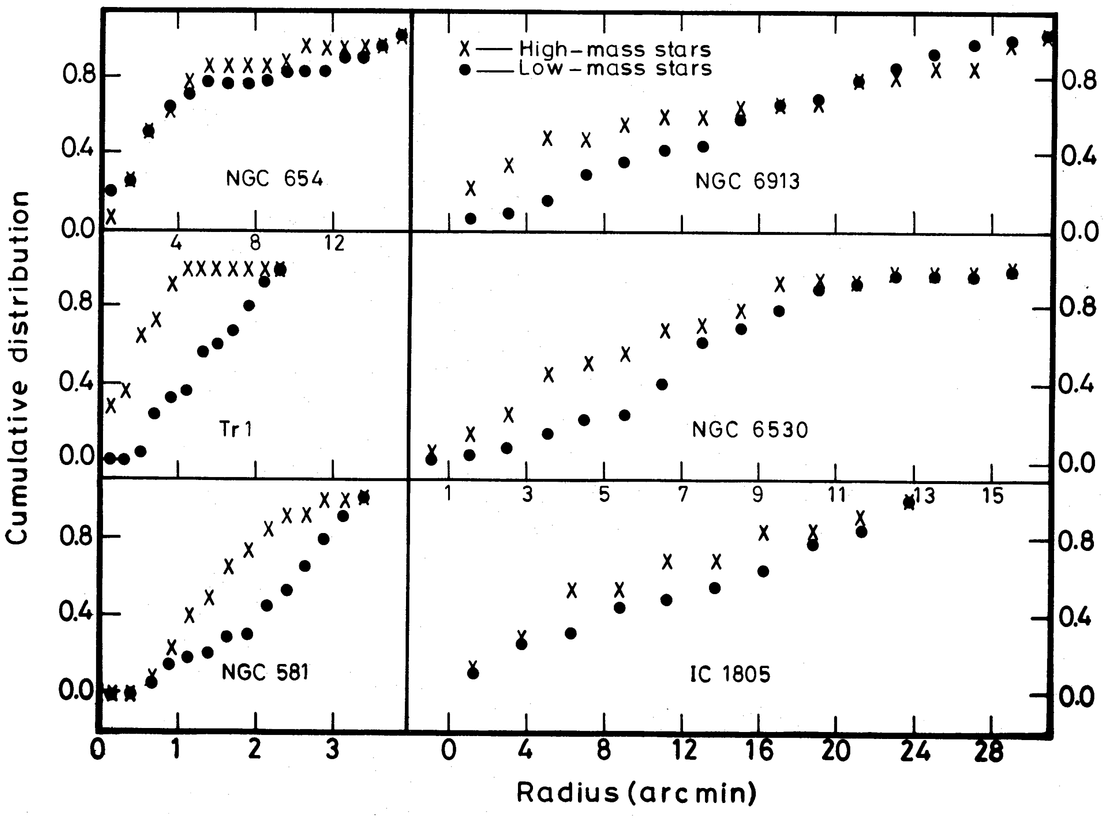

Figure 5. Cumulative radial distribution of the cluster members in the mass groups of NGC 581, Tr 1, NGC 654, IC 1805, NGC 6530 and 6913.

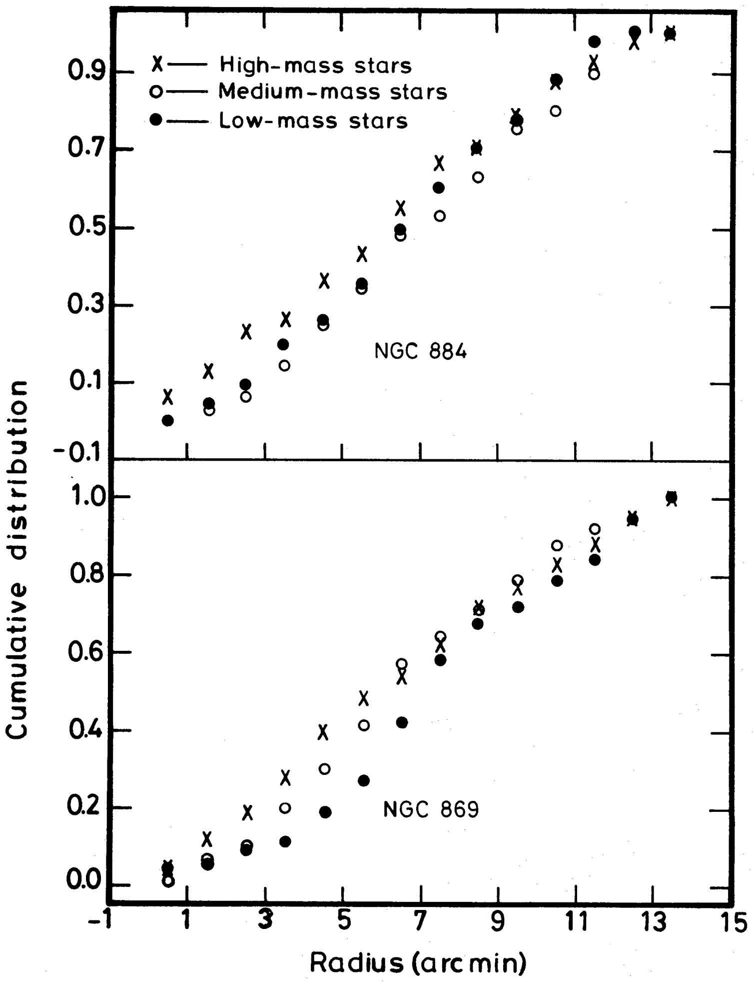

Figure 6. Cumulative radial distribution of the cluster members in the mass groups of NGC 869 and 884.

segregation is clearly evident for all the clusters except NGC 654. Two-sample Kolmogorov–Smirnov and median statistical tests have been used to estimate the significance level of the difference between these distributions. The confidence levels in per cent are listed in Table 4. Both statistical tests as well as the difference in the slopes of both mass groups (see Table 3) yield similar confidence levels. Except for NGC 654, the confidence level is generally higher than 90 per cent. In the case of NGC 869 and 884, the Kolmogorov–Smirnov test rejects the hypothesis that high-mass and medium-mass groups both have the same distribution at 70 and 97 per cent confidence levels respectively. Similarly, the medium mass group is different from the low-mass group at 91 and 53 per cent confidence levels respectively. Present analysis indicates that the differences in the mass groups of IC 1805, NGC 581, 869, 884, 6530, 6913 and Tr 1 have statistical significance.

5.4 RADIUS ESTIMATES FOR MASS GROUPS

We list in Table 4 estimated average radii, radial distances of centre of mass and median radii for low-mass and high-mass stars in each cluster. All the three radii for low-mass stars are larger by a factor of 1.1–2.7 than those of high-mass stars except in the case of NGC 654 (see Table 4). This again indicates more central concentration of high-mass stars in comparison to low-mass stars for NGC 581, 869, 884, 6530, 6913, Tr 1 and IC 1805.

Table 4. Results of statistical test along with mean, centre of mass and median radii for low-mass and high-mass stars of cluster.

Cluster	Confidence level in % by		Radius in units of cluster radius used in this work					
			Low-mass stars			High-mass stars		
	Kolmogorov-Smirnov test	Median test	Average	Centre of mass	Median	Average	Centre of mass	Median
NGC 581	99.5	99.6	0.65	0.65	0.69	0.45	0.44	0.44
Tr 1	99.9	99.7	0.58	0.58	0.57	0.22	0.20	0.19
NGC 654	37	57	0.32	0.34	0.19	0.27	0.17	0.21
NGC 869	99	91	0.55	0.55	0.53	0.48	0.44	0.44
NGC 884	91	90	0.51	0.50	0.51	0.47	0.44	0.46
IC 1805	91	90	0.51	0.52	0.55	0.36	0.40	0.29
NGC 6530	95	95	0.47	0.47	0.46	0.34	0.31	0.30
NGC 6913	93	84	0.56	0.56	0.56	0.48	0.42	0.37

6 Dynamical stage of the clusters

Before deriving the conclusions from the studies of the last section, it is necessary to know whether the location of stars in clusters is representative of their initial distribution resulting from the processes of star formation or not. For this, the dynamical relaxation time, T_{E}, of the cluster has been estimated using

$$T_{\mathrm{E}}=8.9\times10^5\frac{(NR_{\mathrm{h}}^3)^{1/2}}{(\langle m\rangle)^{1/2}}\frac{1}{\log(0.4N)},$$

where N is the number of cluster members, R_{h} is the radius containing half of the cluster mass and $\langle m\rangle$ is the average mass of cluster stars (Spitzer & Hart 1971). There are problems in estimating R_{h} because it requires knowledge of total cluster mass, its spatial distribution and angle between cluster plane and observer's line-of-sight, which are currently unknown. The total cluster mass cannot be estimated simply by summing the individual masses of observed cluster stars because the limiting masses of the clusters are in the range of 1.2–9 $M_{\odot}$ (see Table 2) and if one believes that the slope of the initial mass function is the same up to the lowest mass formed in the cluster [according to Scalo (1986), this statement is debatable], then a significant fraction of the total cluster mass comes from the unobserved stars of the cluster. Consequently, actual estimation of R_{h} is impossible. In such a situation, we assume that R_{h} is equal to half of the cluster radius listed in column 3 of Table 2. This angular value is converted into a linear by taking the cluster distance from Becker & Fenkart (1971) for NGC 869 and 884 and from Sagar (1985) for others. The values of N and $\langle m\rangle$ are taken from the catalogues used in this analysis. In this way, finally, we have been able to estimate T_{E} for each cluster. Columns 5 and 6 of Table 2 list logarithm of cluster age (t) and T_{E} respectively. Ages are taken from Lyngå's (1981) catalogue for NGC 869 and 884 and from Paper II for others. Owing to faint unobserved stars of the clusters, the value of N used in the estimation of T_{E} is the lowest while that of $\langle m\rangle$ is the highest. We also hope that present value of R_{h} is the lowest value of actual R_{h}. All these indicate that the actual value of T_{E} is larger than the one reported in Table 2.

We have also made an estimate of the time required for equipartition of energy amongst cluster members. Again from Spitzer & Hart (1971), we obtain

$$\frac{(T_{\mathrm{eq}})_2}{T_{\mathrm{E}}}=\frac{n_{\mathrm{f}}m_{\mathrm{f}}}{n_1m_2}$$

and

$$\frac{(T_{\mathrm{eq}})_2}{(T_{\mathrm{eq}})_1}=\frac{n_2m_1}{n_1m_2}.$$

Here $(T_{\mathrm{eq}})_1$ and $(T_{\mathrm{eq}})_2$ are respectively the equipartition time for first and second components when only two components are present; n_1, n_2 are the number of stars in first and second components and m_1, m_2 their masses. The value of $n_{\mathrm{f}}m_{\mathrm{f}}$ can be written as:

$$n_{\mathrm{f}}m_{\mathrm{f}}=n_1m_1+n_2m_2.$$

Considering stars of the massive group as second component, we find $0.5<(T_{\mathrm{eq}})_1/T_{\mathrm{E}}<2.5$ for low-mass stars and $0.4<(T_{\mathrm{eq}})_2/T_{\mathrm{E}}<2.4$ for high-mass stars. It means that the equipartition time is not too different from the relaxation time.

A comparison of cluster age with its relaxation time (see Table 2) indicates that the latter is always greater than the former, except for Tr 1. Thus, one can conclude that dynamical evolution has taken place only in Tr 1.

7 Discussions and conclusions

In this work we have studied 11 young open clusters. The various studies reported in Section 5 indicate that the effects of mass segregation are present only in the members of seven clusters namely NGC 581, 869, 884, 6530, 6913, Tr 1 and IC 1805. Amongst these clusters evidence for the presence of mass segregation is also shown by Vogt (1971) in NGC 869 and 884; and by McNamara & Sekiguchi (1986) in NGC 6530. In some other clusters also this effect has been noticed, e.g. by Kholopov & Artyukhina (1972) and van Leeuwen (1980) in the Pleiades; by Solomon &McNamara (1980) and Mathieu (1983) in M 11; by McNamara & Sekiguchi (1986) in M 35; by Herbst & Miller (1982) in NGC 3293; by Artyukhina (1972) in the α Per cluster; by King (1983) in NGC 3532 and 6087; and by Archemashvili (1976) in M 37. More recently, Mathieu & Latham (1986) have observed that massive binaries are centrally concentrated relative to the single low-mass stars in the old open cluster M 67. Thus one can say that there is clear evidence of mass segregation in many open clusters, whatever be the reason for this. This effect has long been pointed out by Kholopov and co-workers (*cf.* Kholopov 1969).

The effect of mass segregation is understood in terms of dynamical relaxation of a cluster, which leads to equipartition of kinetic energy in cluster members, with the result that low-mass stars occupy a larger volume than the massive stars. But if we rely on the conclusions of the last section that except, for Tr 1, the clusters studied here are not dynamically relaxed and hence, that the present stellar distribution in these clusters may be regarded as nearly the distribution of stars at the time of star formation, then the observed mass segregation in NGC 581, 869, 884, 6530, 6913 and IC 1805 might have taken place at the time of star formation. This conclusion is in agreement with the finding of Larson (1982).

The estimates of T_{E} and T_{eq} in the last section assume that relaxation in a cluster is taking place mainly through cumulative long-range gravitational scattering. For young open clusters with $\leqslant 100$ members, i.e. for the type of clusters under discussion, close gravitational encounters are more important than long-range gravitational relaxation. *N*-body calculations that treat close gravitational encounters and binary formation indicate that dynamical evolution is more rapid (by an order of magnitude) than what T_{E} indicates, and presence of a mass spectrum further accelerates the relaxation (see Wielen 1975; King 1980; Terlevich 1987). In addition, the relaxation time depends upon the location in the cluster and varies with a significant radial gradient throughout the cluster (Spitzer & Hart 1971). How this affects the cluster structure and hence the dynamical processes is not well understood. On the other hand, the value of T_{E} listed in Table 2 is a lower limit (see Section 6). How much the actual value of T_{E} differs from the one given in the Table 2 is at present unknown.

However, in this context recent studies by Lada, Margulis & Dearborn (1984) and Margulis & Lada (1984) are relevant. They have studied dynamical evolution of young open clusters with members $\leqslant 100$ by incorporating a typical initial mass spectrum and the dissipation of a gas cloud out of which the cluster formed but assumed no initial mass segregation or equipartition of energy. These studies indicate that as a result of two body interactions some mass segregation may occur after a time (~ 2–3×10^6 yr) substantially longer than that necessary for the gas removal from the cluster. This time is more than the ages of NGC 6530, 6913 and IC 1805 (see Table 2) and the presence of variable interstellar extinctions in these cluster regions (*cf.* Sagar 1987b) indicates that gas out of which clusters formed is still present in the clusters. Therefore, the observed mass segregation in NGC 6530, 6913 and IC 1805 may be the imprint of star formation processes in the clusters and the assumption of no initial mass segregation used in the above theoretical calculations may not be justified.

In conclusion, we believe that during the formation of a cluster, high-mass stars preferentially form in a localized region towards the cluster centre, whereas the lower mass stars form in a more extended region across the cluster field. It is worth pointing out here that the stars under consideration are all rather massive, i.e. even the low-mass stars have masses more than 2 $M_\odot$ and the situation for less massive stars is still far from clear. The present analysis also suggests that observed mass segregation in intermediate age and in NGC 581, 869 and 884 type open clusters might be due to a combination of both initial star formation conditions and dynamical relaxation processes.

In any case, a better understanding of dynamical evolution of poor and medium young open clusters is desirable to throw more light on the observed mass segregation in these objects.

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