THE AGE DISTRIBUTION AND TOTAL LIFETIMES OF OPEN CLUSTERS

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Abstract. The age distribution of galactic clusters is obtained from well-observed star clusters, and it is concluded that the observed age distribution of clusters within 1000 pc is not seriously affected by the selection effects. If we assume that the rate of formation of clusters is constant, the observed age distributions of clusters for Trumpler's different richness classes have been obtained; and it is found that the rich clusters have longer lifetimes than the poor clusters.

The lifetimes of clusters $\log(\tau_{1/2})$ for different richness classes obtained in the present study differ significantly from the lifetimes obtained by Janes and Adler (1982), because the lifetimes obtained by Janes and Adler may have been affected by the age-dependent selection effects which grow with increasing distance. From the observed age distribution of all clusters within 1000 pc the results obtained in the present study are in close agreement with the lifetimes obtained by Wielen (1971a).

1. Introduction

An analysis of the observed galactic clusters indicates that the number of clusters decreases with age (Oort, 1958; von Hoerner, 1958). This has been attributed to a process of dynamical dissolution of clusters. Wielen (1971a) obtained the observed age distribution of galactic clusters and also the theoretical dynamical disintegration time by numerical integration of the equations of the motion of all the stars as an N-body problem, taking into account the relevant external forces (Wielen, 1971b) and it was shown that the theoretical lifetimes and the observed values are in sufficient agreement.

Since the observed age distribution obtained by Wielen (1971a) was based on a relatively smaller sample of galactic clusters taken from the catalogue compiled by Lindoff (1968) and Backer and Fenkart (1971), which was then the most well observed material available. Lynga (1982) and Janes and Adler (1982) have made independent studies of cluster longevity based on a larger sample of clusters and the reasonably self-consistent determination of cluster-ages. Lynga (1982) has determined the longevity of the clusters based on the comparison of the observed age distribution of clusters having ages between 10^7 to 10^9 yr, with the assumed model of age distribution, $n(t) = Ne^{-t/T}\Delta t$ for various longevity parameters T, where $n(t)$ is the number of clusters with age t after a time Δt has elapsed, N is the number of clusters formed in unit time interval and Δt is the time interval. However, we have plotted the observed age distribution, obtained by Lynga (1982), along with the computed age distribution in Figures 1(a) and 1(b) for longevity parameter $T = 1 \times 10^8$ and 1.2×10^8 yr, respectively; and we conclude that the observed age distribution is significantly different from that of the age distribution based on the model given by Lynga (1982).

Janes and Adler (1982) have obtained the lifetimes of clusters of different richness

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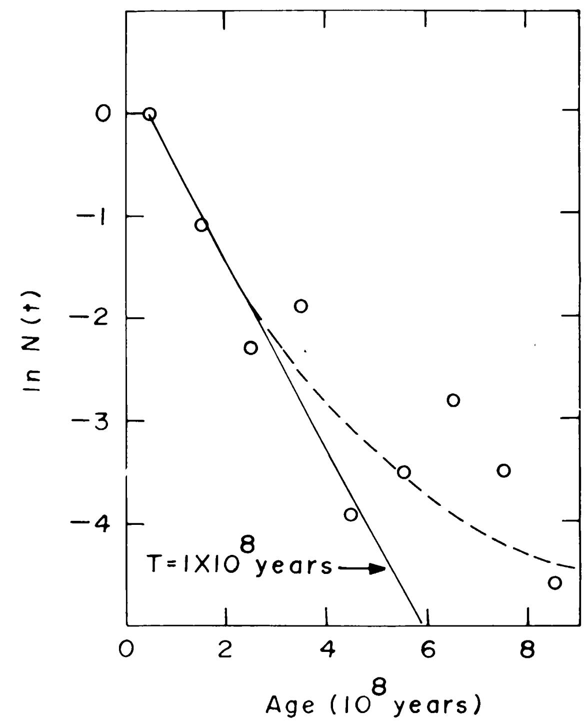

Fig. 1a. Observed age distribution (dashed curve) along with the computed age distribution (solid line) for longevity parameter $T = 1 \times 10^8$ yr.

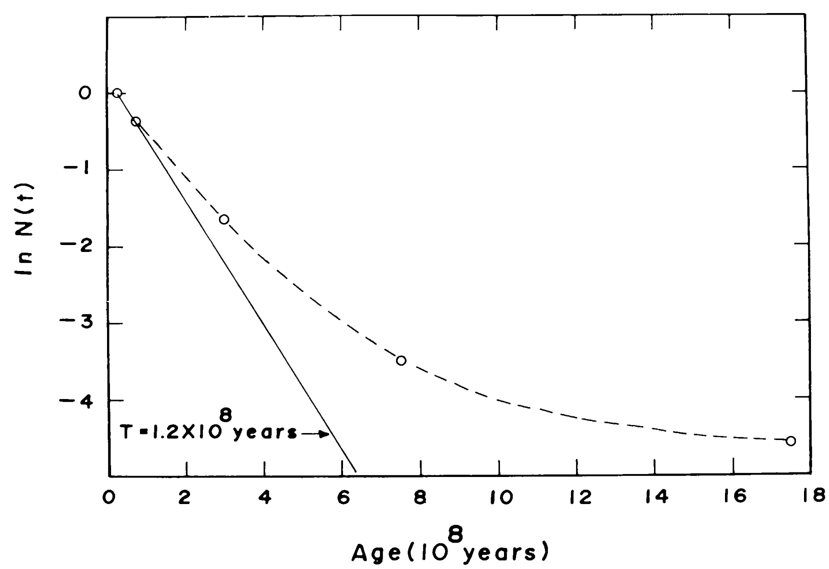

Fig. 1b. Observed age distribution for the present study (dashed curve) along with the computed age distribution (solid line) for the longevity parameter $T = 1.2 \times 10^8$ yr.

classes and it has been concluded that the lifetimes of poor clusters are much shorter than those of rich clusters. However, in the determination of lifetimes of clusters, Janes and Adler (1982) have not considered the age-dependent selection effects and they have included all the clusters in their study. Wielen (1971a) has concluded that the age-dependent selection effects grow with increasing distance and the age distribution of clusters with $r > 1000$ pc differs significantly from that of the nearby clusters with $r \leq 1000$ pc.

In the light of the above discussions it was considered worthwhile to carry out a fresh study of observed age distribution on the basis of a larger sample of clusters and taking into account the richness class and also the age-dependent selection effects.

2. Observational Data and Age Statistics

Lynga (1983) has prepared a computer-based catalogue of open clusters with their distances, ages, and other relevant parameters. In the present study of galactic clusters we have used the cluster data given in this catalogue, because it contains the most consistent material presently available for the open clusters. The age distribution of the galactic cluster for various ranges of distance from the Sun is given in Table I. The resulting frequency $\nu(\tau) = \Delta n / \Delta \tau$ of the clusters within $r \leq 1000$ pc as a function of age τ has been tabulated in the last column of Table I. From Table I it is found that the

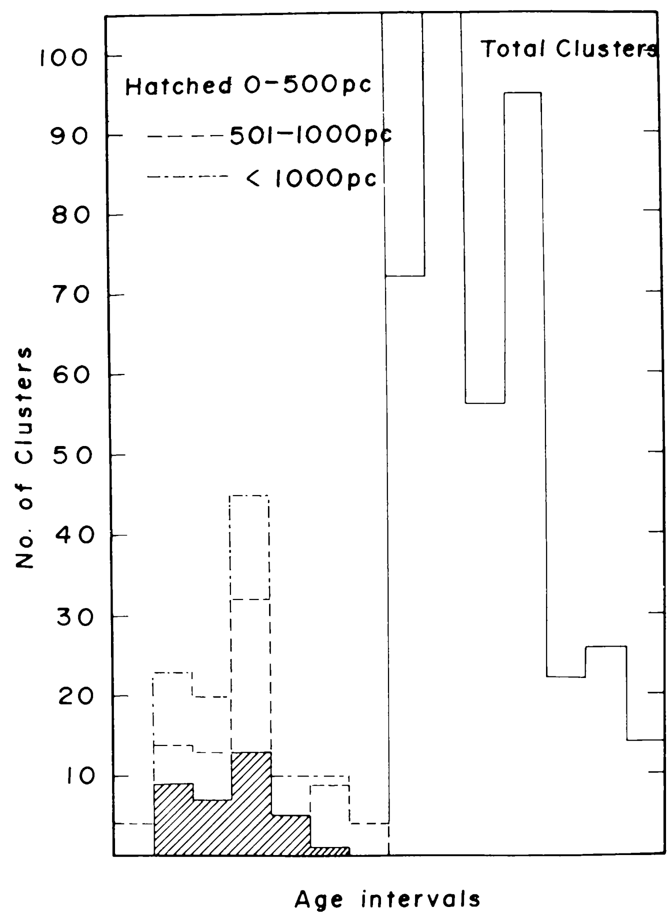

Fig. 2. The distribution of clusters as a function of age for various limiting distances. The age intervals are given in Table I.

TABLE I

Age distribution of galactic clusters of all richness classes

log age (τ)	Number of clusters Δn in the distance range (in pc)						$\Delta\tau$ (10^8 yr)	Age frequency $\nu(\tau) = \Delta n / \Delta\tau$ (clusters 10^8 yr^{-1})
	0–500	501–1000	1001–1500	1501–2000	> 2000	0 – 1000		
$\tau < 7.0$	0	4	7	12	49	4	0.1	40
$7.0 \leq \tau < 7.7$	9	14	24	23	35	23	0.4	58
$7.7 \leq \tau < 8.0$	7	13	14	11	11	20	0.5	40
$8.0 \leq \tau < 8.7$	13	32	26	15	9	45	4	11
$8.7 \leq \tau < 9.0$	5	5	3	5	4	10	5	2
$9.0 \leq \tau < 9.4$	1	9	3	4	9	10	15	0.67
$9.4 \leq \tau$	0	4	0	1	9	4	75	0.05

frequency $\nu(\tau)$ of young open clusters is about 3 orders of magnitude higher than the frequency of the oldest clusters.

The distribution of clusters, as a function of age, for various limiting distances are shown in Figure 2. The age distributions of the galactic clusters in the distance ranges $0 < r \leq 500$ pc and $500 < r \leq 1000$ pc, do not differ systematically. This statement was checked statistically which revealed insignificant difference between the two age distributions of galactic clusters at 0.05 level. The age distribution of all clusters differs significantly from that of the nearby clusters with $r \leq 1000$ pc. Our results are in agreement with the results obtained by Wielen (1971a), where he concluded that the observed age distribution of galactic clusters within the cylinder $r_p \leq 1000$ pc is not seriously affected by selection effects. A significant bias exists for the remote clusters, though. All the selection effects grow with increasing distance. Therefore, for the study of age distribution in the subsequent sections, we shall consider the clusters within a distance of $r \leq 1000$ pc from the Sun. We have also omitted the cluster younger than 10^7 yr to avoid the inclusion of associations.

3. Total Lifetimes

The total lifetime of a cluster is the period between its formation and its total disintegration. From the observed distributions of clusters as a function of age, Janes and Adler (1982) have shown that the lifetimes of poor clusters are much shorter than those of rich clusters. Since we are considering the clusters within a distance of $r \leq 1000$ pc for minimal selection effects, we cannot divide the clusters into large numbers of richness classes similar to those adopted by Janes and Adler (1982) because the number of clusters in each richness class would be very small for an age distribution study. Therefore, we have divided the clusters into three groups, poor, medium, and rich

TABLE II

Age distribution of galactic cluster for different richness classes within $r \leq 1000$ pc

log age (τ)	Poor		Medium		Rich	
	No. of clusters	Age frequency $\nu(\tau)$ (clusters 10^8 yr^{-1})	No. of clusters	Age frequency $\nu(\tau)$ (clusters 10^8 yr^{-1})	No. of clusters	Age frequency $\nu(\tau)$ (clusters 10^8 yr^{-1})
7–7.8	9	17	16	31	5	10
7.8–8.2	6	7	12	13	9	10
8.2–8.6	4	2	14	6	7	3
8.6–9.0	1	0.05	7	1.20	4	0.66
9.0 – 9.4			5	0.33	4	0.27
9.4 – 9.8	1	0.03	0	0	2	0.05
9.8–10.0	0	0	0	0	1	0.03

according to the Trumpler class assigned to the clusters in the catalogue compiled by Lynga (1983).

The total lifetime of galactic clusters in each richness class has been statistically deduced from the observed age distribution $\nu(\tau)$. The age distribution for each richness class is given in Table II. It is evident from Tables I and II that the observed frequency $\nu(\tau)$ decreases with cluster age τ. This decrease in the observed frequency is due to the disappearance of clusters caused by their dynamical dissolution with time. We have used the relation for the observed frequency $\nu(\tau)$ (cf. Wielen, 1971a)

$$\nu(\tau) = \nu(0)P(\tau),$$

where $P(\tau)$ is the percentage of the clusters which will reach the age τ. $\nu(0)$ is the initial frequency of the clusters. The relation between $P(\tau)$ and age τ for different richness classes is plotted in Figure 3.

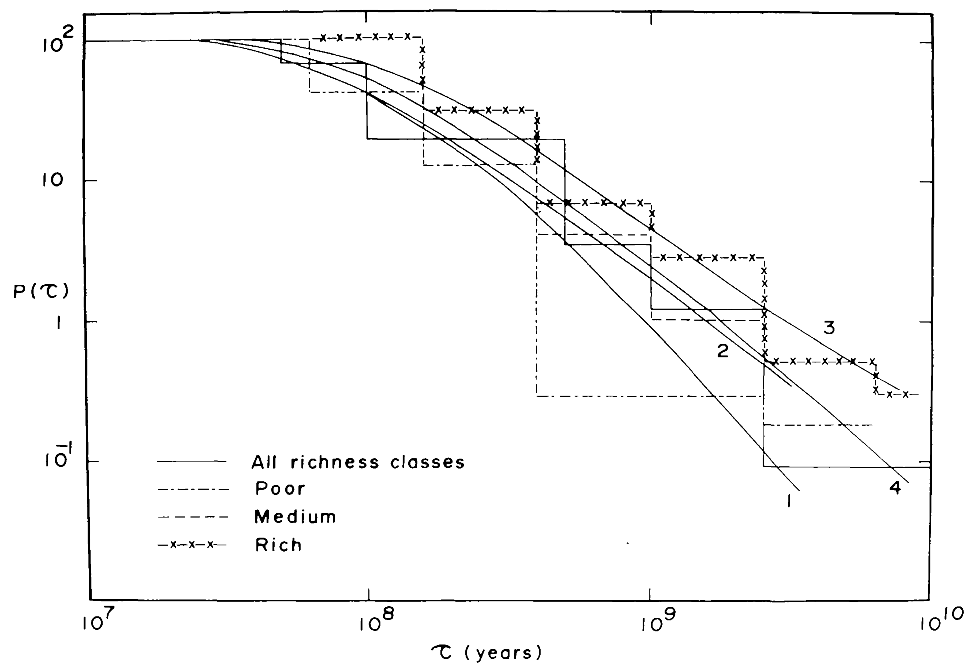

Fig. 3. The relation between $P(\tau)$ and age τ for different richness classes and for all clusters within 1000 pc. The curves numbered 1, 2, 3, and 4 are for poor, medium, rich, and all combined richness classes, respectively.

The total lifetimes of galactic clusters, obtained for different richness classes, are given in Table III, and we conclude that the lifetimes of clusters depend on their richness class. The rich clusters have longer lifetimes than the poor clusters. Our conclusions are in agreement with the findings of Janes and Adler (1982). However, we find that there is significant difference between the lifetimes of clusters $\log(\tau_{1/2})$ obtained by Janes and Adler (1982) and the lifetimes obtained in the present study. The lifetimes of poor and medium clusters obtained by Janes and Adler (1982) are considerably less than those

TABLE III

Total lifetimes of galactic clusters

Richness class	No. of clusters	Initial frequency $\nu(0)$ (clusters 10^8 yr^{-1})	Fraction of newly formed clusters that will survive over a period of τ (10^8 yr)					
			50%	20%	10%	5%	2%	1%
Poor	21	17	0.8	1.8	2.8	4.3	6.6	9.1
Medium	54	31	0.8	1.9	3.1	5.1	10.0	15.8
Rich	32	10	1.4	3.4	5.4	8.9	17.8	28.8
All	112[a]	58	1.0	2.4	3.9	6.2	11.2	17.8
All (Wielen, 1971a)	59	30	1.6	3.0	4.5	6.0	10.0	13.0

[a] The richness class has not been assigned for 5 clusters in the catalogue compiled by Lynga (1983).

obtained by us. On the contrary, the lifetimes of rich clusters obtained by us are considerably less than the lifetimes obtained by Janes and Adler (1982). The difference between the two lifetimes can be explained on the basis of the age distribution of the clusters for various richness classes within $r \leq 1000$ pc and the age distribution of all clusters without any consideration for their distances. The age distribution of all clusters for different richness classes differs significantly from the age distribution of clusters within $r \leq 1000$ pc. The relative frequency of younger clusters of poor and medium classes among all clusters is considerably higher than the relative frequency of similar

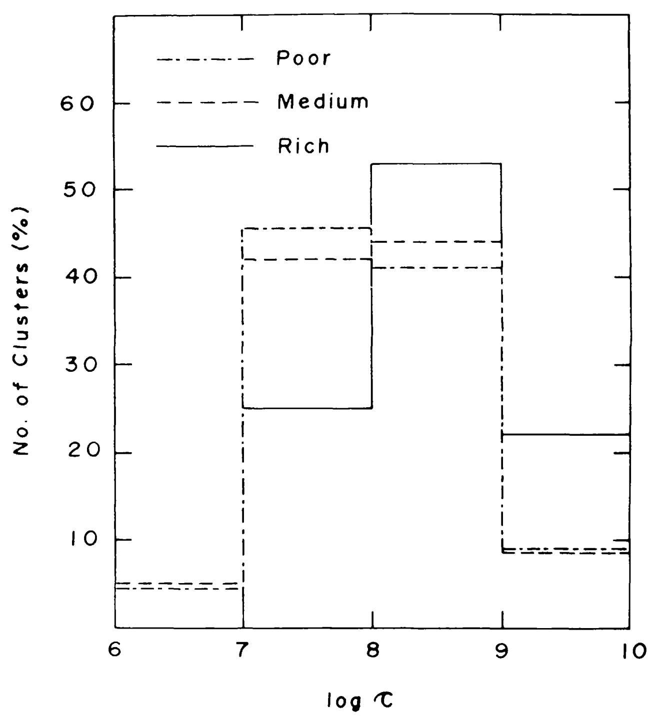

Fig. 4. The percentage of clusters in different age groups for various richness classes within 1000 pc.

younger clusters among clusters within $r \leq 1000$ pc. This difference between the two distributions is due to the fact that it is more difficult to detect poor and medium old clusters among the field stars as than similar young clusters because young clusters contain brigher and bluer stars. Also, photometric observers may favour these clusters when studying te spiral structure of the galaxy. The rich clusters are comparatively older and the relative frequency of clusters older than 10^9 yr is higher at a distance $r > 1000$ pc as than their relative frequency within a distance of 1000 pc.

The percentage of clusters in different age groups for various richness classes have been plotted in Figures 4 and 5 for clusters with $r \leq 1000$ pc and all clusters, respectively. From the present study and the selection effects studied by Wielen (1971a), it is concluded that the age-dependent selection effects grow with increasing distance and the age distribution of clusters within a distance of 1000 pc is not seriously affected by such selection effects. Therefore, the lifetimes obtained by Janes and Adler (1982) may have been affected by the selection effects.

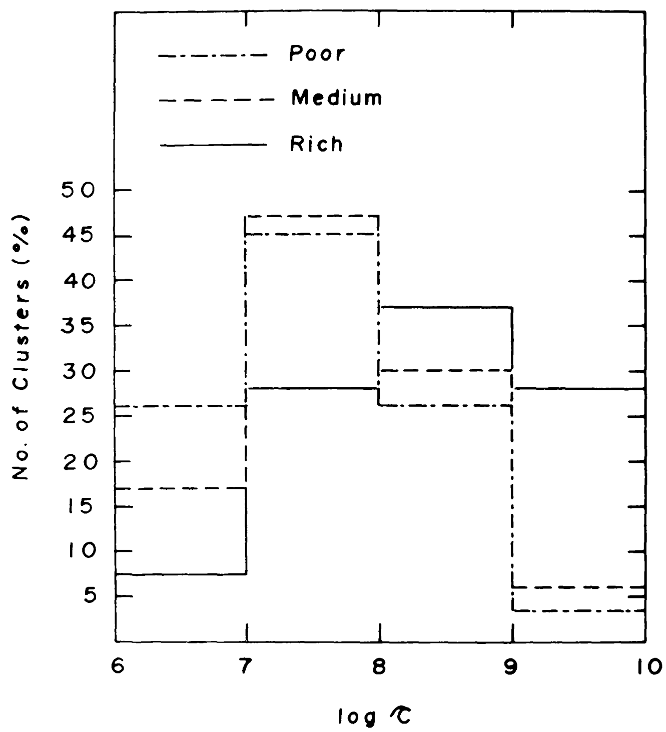

Fig. 5. The percentage of all cluster in different age groups for various richness classes.

In Figure 3 we have also plotted the age distribution of all clusters within 1000 pc to compare our results with those obtained by Wielen (1971a). The results thus obtained are given in Table III. The lifetimes obtained in the present study are in close agreement with the lifetimes obtained by Wielen (1971a).

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