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THE YOUNG OPEN STAR CLUSTERS: STABILITY AND STRUCTURE

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ABSTRACT

It is found that the differential extinction $\Delta E(B-V)$ in open clusters, which may be due to the presence of gas and dust, decreases systematically with the age of the cluster. Consequently we can infer that the average gas removal time must be about 10^8 yr. The present work supports the findings of Elmegreen (1983) that bound clusters are formed in low-mass clouds ($\mathscr{M} \leqslant 10^4 \mathscr{M}_\odot$) while the unbound OB associations are formed in clouds having higher masses ($\mathscr{M} > 10^5 \mathscr{M}_\odot$). It is also concluded that if formation of bound clusters takes place in low-mass clouds ($\mathscr{M} \sim 10^4 \mathscr{M}_\odot$) only, then the observed low cluster formation rate and higher space density of low-mass clouds suggest that star formation in open clusters must be a continuous process for about 10^8 yr. The present work also supports the existence of a corona around open clusters and it is concluded that the coronal regions in bound open clusters are dynamically stable in the tidal forces of the Galaxy.

I. INTRODUCTION

Studies related to the stability and structure of galactic open clusters help in understanding the star-formation process in our galaxy, since these depend upon physical conditions of the molecular clouds from which star clusters are formed. It is believed that most of the disk stars in the galaxy were initially members of unbound associations (Roberts 1957; Miller and Scalo 1979). Formation of associations takes place in giant molecular clouds where the star-formation efficiency (SFE) i.e., conversion of gaseous mass to stellar mass, is low (Duerr, Imhoff, and Lada 1982; Elmegreen 1983). The recent studies indicate that the probability of formation of unbound clusters in our galaxy is quite high because the star-formation process is itself a destructive and inefficient process (Lada, Margulis, and Dearborn 1984). However, the existence of about 115 bound open clusters, within 1 kpc of the Sun having a typical lifetime of about 10^8 yr (Pandey and Mahra 1986), leads to an interesting problem for star-formation studies. The studies of galactic clusters which are gravitationally bound provide important clues to the process of star formation. The formation of bound cluster systems can be explained on the basis that the molecular clouds from which these are formed are either dispersed slowly after appearance of the cluster; or the clouds must attain a star-formation efficiency of about 50% if the cloud disruption is sudden (Elmegreen 1983; Mathieu 1983; Wilking and Lada 1983; Lada, Margulis, and Dearborn 1984). The highest efficiency in star-forming regions is estimated to be about 30% for the dark Ophiuchi cloud (Wilking and Lada 1983; Lada and Wilking 1984). However, Lada *et al.* (1984) have theoretically obtained that the molecular clouds with SFEs > 21% can produce bound open cluster systems if the gas removal time τ_g is considered to be about 5×10^6 yr. Therefore, it is considered important to estimate the SFE and τ_g to understand the evolution of molecular clouds leading to formation of bound open clusters.

The stability of an open cluster in our galaxy also depends upon its structure. Kholopov (1969) has concluded that the nucleus and the corona are two main regions in open clusters, which has been further supported by Danilov *et al.* (1985). The nucleus region of clusters contains relatively bright and massive ($\geqslant 3 \mathscr{M}_\odot$) stars and consequently it is a well-studied region of the clusters. However, the corona of star clusters, which generally contains a large number of faint stars, has not been studied in detail. In fact the spatial distribution of these faint and low-mass stars ($\sim 1 \mathscr{M}_\odot$) defines the actual boundary of the clusters and consequently has an important bearing on studies related to the initial mass function (IMF), structure, and evolution of open clusters.

In the present study, based on the available photometric observations, an effort has been made to estimate the boundaries, the gas removal time τ_g, and the SFEs for a few open clusters.

II. OBSERVATIONAL DATA

The photometric data of the open clusters used in the present study have been taken from the catalog of Mermilliod (1986) and the stellar masses have been taken from the catalogs of Myakutin *et al.* (1984) and Piskunov (1983). The photoelectric photometric data of young open clusters (age$\leqslant 5 \times 10^7$ yr) have been used to obtain the differential interstellar extinction for estimating the gas mass. The masses of the member stars have been used to estimate the total stellar mass of the clusters. The estimated mass of the matter associated with the clusters and the total stellar mass of the clusters have been used to obtain the SFEs in the open clusters and also to study their stability and structure.

III. FORMATION OF BOUND SYSTEMS

The most important parameters required to explain whether a newly formed star cluster will be a bound or an unbound system are the gas removal time τ_g, which is the timescale over which the unused gas is removed from the vicinity of newly formed stars, and the star-formation efficiency (SFE).

a) Gas Removal Time (τ_g)

It is believed that the molecular cloud regions are the birthplaces for star clusters as young stellar systems; e.g., the

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stars in the molecular clouds in ρ Ophiuchus (Vrba *et al.* 1975; Wilking and Lada 1983) and heavily obscured cluster members in Ara (Koornneef 1977) are still embedded in dust and gas clouds and it is assumed that with time the gas and dust in these clouds will either be used up in star-formation processes or will be dispersed away by radiation pressure due to massive stars present in these systems. Therefore, in young open clusters (age $< 10^8$ yr) the presence of a variable amount of unused gas and dust is expected inside the boundaries and consequently a nonuniform interstellar extinction is observed.

The interstellar extinction has been estimated from the $(U-V)$ and $(B-V)$ color–color diagram of the clusters (cf. Johnson and Morgan 1953; Becker and Stock 1954). It is a well-observed fact that photometric sequences of open clusters exhibit different dispersions in interstellar extinction. Apart from the differential extinction, the other possible reasons for the observed dispersion are stellar evolution, stellar duplicity, stellar rotation, difference in chemical composition, dispersion in ages, dispersion in distances, presence of nonmember stars, and inaccuracies in the photometric data (cf. Burki 1975; Sagar 1985, 1987). However, these factors (excluding the differential extinction) can produce a maximum dispersion $\Delta \mathrm{E}(B-V) = 0.11$ mag for main-sequence stars, where $\Delta \mathrm{E}(B-V) = \mathrm{E}(B-V)_{\max} - \mathrm{E}(B-V)_{\min}$.

Thus, based on the above discussions it is concluded that the value of $\Delta \mathrm{E}(B-V) > 0.11$ mag indicates the presence of nonuniform gas and dust within the clusters. This conclusion is also supported by the recent near-infrared photometric studies of open clusters (cf. Tapia *et al.* 1988; Roth 1988; Sagar and Yu 1989a,b).

We have used the catalog of Mermilliod (1986) to study the age dependence of nonuniform extinction in open clusters. The values of $\Delta \mathrm{E}(B-V)$ have been estimated only for those clusters in which the photoelectric photometric observations of 30 or more cluster stars are available, and out of 173 such clusters 64 show a variable reddening $\Delta \mathrm{E}(B-V) > 0.11$ mag. The ages of the clusters have been taken from the catalog of Lyngå (1987a). From the age dependence of $\Delta \mathrm{E}(B-V)$ of the clusters shown in Fig. 1, it is found that the differential extinction shows a systematic variation with age and the gas removal time for the sample of the clusters used in the present study is estimated to be larger than 10^8 yr.

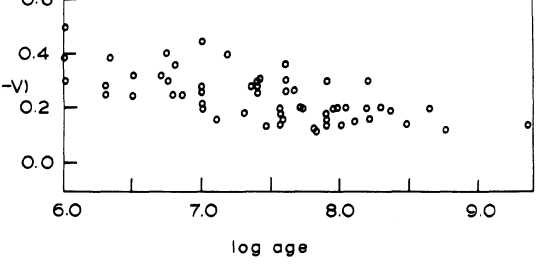

FIG. 1. Variation of $\Delta\, \overline{\mathrm{E}(B-V)}$ with age of the clusters.

b) Estimation of Gas Mass

Using the value of average differential extinction due to the interstellar matter which is assumed to be coexistent with the cluster stars, the gas mass or the boundary of the cluster can be estimated if either of these parameters is known. Assuming that (1) the distribution of the matter is spherically symmetric, (2) the average density of the matter is uniform throughout the sphere, and (3) the amount of dust is insignificant as compared to hydrogen in the matter, a relation between the gas mass, the radius of the cloud, and the extinction can be obtained using hydrogen line densities.

Bohlin, Savage, and Drake (1978) have obtained an average value of $N_{\Sigma \mathrm{H}}/\mathrm{E}(B-V) = 5.8\times 10^{21}\ \mathrm{cm}^{-2}\ \mathrm{mag}^{-1}$ with an estimated error of about 6%. Using this relation and taking $A_v = 3\Delta\, \overline{\mathrm{E}(B-V)}$, the line density of hydrogen comes out to be $0.0032\ A_v\ \mathrm{g\ cm}^{-2}$. The extinction $\Delta\, \overline{\mathrm{E}(B-V)}$ due to the unprocessed gas present in the system has been obtained by subtracting $\mathrm{E}(B-V)_{\min}$ from the mean value of the extinction, $\mathrm{E}(B-V)_{\mathrm{mean}}$. Further considering that the matter is uniformly distributed in a sphere of radius r, the density of the hydrogen comes out to be $0.0032\ (A_v/r)\ \mathrm{g\ cm}^{-3}$. Thus the mass of the hydrogen can be obtained using the relation

$$\mathscr{M}_{\mathrm{gas}} = 1.34\times 10^{-2} A_v r^2 \quad \mathrm{g}. \tag{1}$$

However, in estimating the gas mass present in the cluster using the above relation, the uncertainty due to the assumptions stated above must be kept in mind.

c) Star-Formation Efficiency (SFE)

The estimates of SFE are available for only a few regions; e.g., it is estimated that the SFE is about 20% in NGC 7023 (Elmegreen 1980) and L43 (Elmegreen and Elmegreen 1979) and about 40% in ρ Oph (Wilking and Lada 1983).

Several studies have been carried out suggesting that the formation of bound cluster systems requires an SFE value of 50% where the cloud disruption is sudden and of nearly 30% where cloud disruption takes place in about 3×10^6 yr (Elmegreen 1983; Mathieu 1983; Lada, Margulis, and Dearborn 1984). It has also been concluded that in the cases of slow rate of gas removal from the system, a lower SFE value of ~15% may also produce a bound cluster system (Lada, Margulis, and Dearborn 1984).

Since Fig. 1 manifests that the gas removal is a slow process, it is reasonable to assume that young clusters having age $< 2\times 10^7$ yr may not have lost a significant amount of gas from the system.

The total mass of the gas, $\mathscr{M}_{\mathrm{gas}}$, present in the cluster has been estimated using Eq. (1) and the observed absorption due to unprocessed gas present in the system. The values of radius r of the cluster fields have been estimated from the boundaries defined by the locations of the observed member stars in each cluster. The total mass of the stellar content, $\mathscr{M}_*$ has been obtained by summing up the masses of the individual member stars present in the cluster region having radius r. The values of SFEs, $\epsilon_1 = \mathscr{M}_*/\mathscr{M}_* + \mathscr{M}_{\mathrm{gas}}$, thus obtained for different clusters are given in Table I. The estimated statistical error in the determination of ϵ_1 comes out to be nearly 15% where $\Delta\, \overline{\mathrm{E}(B-V)}$ is 0.30 mag. However, the error increases for clusters having lower values of $\Delta\, \overline{\mathrm{E}(B-V)}$. The estimated statistical error is about 25%

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TABLE I. Star-formation efficiencies (ϵ_1) in different clusters.

Cluster	Radius r of cluster field (arcmin)	Distance (pc)	Linear radius (pc)	Extinction $\overline{\Delta E(B-V)}$ due to the unprocessed gas (mag)	Mass of gas $\mathscr{M}_{\rm gas}$ ($\mathscr{M}_\odot$)	Mass of member stars $\mathscr{M}_*$ ($\mathscr{M}_\odot$)	SFE	Remarks
NGC 654	16	2340	10.9	0.20	4 613	341	0.07	unbound
NGC 2264	20	800	4.7	0.08	343	324	0.49	see text
NGC 6530	16	1820	8.5	0.10	1 403	427	0.23	bound
NGC 6611	15	3160	13.8	0.20	7 394	975	0.12	possibly bound
NGC 6823	15	3470	15.1	0.25	11 066	791	0.07	unbound
NGC 6913	15	1500	6.6	0.37	3 129	472	0.13	possibly bound
IC 1805	25	2400	17.5	0.28	16 647	1300	0.07	unbound
Tr 1	2.4	2290	1.6	0.15	75	148	0.66	bound
NGC 2571*	6	2050	3.6	0.21	528	209	0.28	bound
NGC 7380 *	14.3	3600	15	0.34	14 851	480	0.03	unbound
IC 2581*	9.2	2300	6.2	0.31	2 313	501	0.18	bound

Notes to TABLE I.

Photometric data for open clusters have been taken from Myakutin *et al.* (1984) except for those marked with an asterisk, which have been taken from Piskunov (1983).

for clusters having Δ $\overline{E(B-V)}$ ~0.10 mag.

A more realistic value of SFE can be obtained by comparing the present-day stellar density to the initial density of the molecular cloud. However, such a comparison requires knowledge of the total mass of the cluster and the mass of the parent cloud.

The distribution of stars in a cluster can be represented by the following power law:

$$N \propto \int \mathscr{M}^{\alpha}\, d\mathscr{M},$$

where N is the number of stars in a cluster, $\alpha = x - 1$, and x is the slope of the mass function. The total stellar mass of the cluster $\mathscr{M}'_*$ can be obtained by using the following relation:

$$\mathscr{M}'_* = C \int_{\mathscr{M}_{\rm L}}^{\mathscr{M}_{\rm U}} \mathscr{M}^{\alpha} \mathscr{M}\, d\mathscr{M},$$

where $\mathscr{M}_{\rm U}$ and $\mathscr{M}_{\rm L}$ are the upper and lower limits for stellar masses in the cluster. The values of the slope x and constant C are obtained for each cluster and have been used to estimate the total stellar mass of the cluster. Since Larson (1985) has concluded that fragmentation becomes less likely for masses below about 0.3 $\mathscr{M}_\odot$, we have assumed a lower mass limit of $\mathscr{M}_{\rm L} = 0.3\,\mathscr{M}_\odot$. However, the total mass of the clusters has also been obtained assuming $\mathscr{M}_{\rm L} = 0.1\,\mathscr{M}_\odot$.

Larson (1982) has found that the mass of the most massive star, $\mathscr{M}_{\rm star}$, associated with the cloud, increases systematically with $\mathscr{M}'_{\rm gas}$, the mass of the molecular cloud, and it can be represented by the equation

$$\mathscr{M}_{\rm star} = 0.33\, \mathscr{M}'^{\,0.43}_{\rm gas}. \qquad (2)$$

The above relation has been used to obtain the mass of the gas cloud which is associated with a cluster having a star as massive as $\mathscr{M}_{\rm star}$. The SFEs, $\epsilon_2 = \mathscr{M}'_*/\mathscr{M}'_* + \mathscr{M}'_{\rm gas}$, thus obtained are given in Table II. The average estimated statistical error in the determination of ϵ_2 is about 20%.

In general, the star-formation efficiencies ϵ_1 and ϵ_2 are in fair agreement except for NGC 2264. The value of ϵ_1 suggests that the SFE in NGC 2264 is quite high (56%), while the value of ϵ_2 (1%) is extremely low. Possible reasons for this discrepancy are the following: (1) Since the value of Δ $\overline{E(B-V)}$ is 0.08 mag, therefore the error in the determination of ϵ_1 comes out to be 30%. (2) The high value of ϵ_1 (56%) may be due to underestimation of Δ $\overline{E(B-V)}$ and also due to inclusion of nonmember massive stars in obtain-

TABLE II. Star-formation efficiencies (ϵ_2) in different clusters.

Cluster	Mass of most massive star ($\mathscr{M}_\odot$)	Mass of gas $\mathscr{M}'_{\rm gas}$ ($\mathscr{M}_\odot$)	Total stellar mass of cluster ($\mathscr{M}_\odot$) ($\mathscr{M}_{\rm L} = 0.1\mathscr{M}_\odot$)	Total stellar mass of cluster ($\mathscr{M}_\odot$) ($\mathscr{M}_{\rm L} = 0.3\mathscr{M}_\odot$)	SFE ($\mathscr{M}_{\rm L} = 0.1\mathscr{M}_\odot$)	SFE ($\mathscr{M}_{\rm L} = 0.3\mathscr{M}_\odot$)	Remarks
NGC 654	11.5	3 829	902	686	0.19	0.15	possibly bound
NGC 2264	39.9	69 180	1 470	703	0.02	0.01	unbound
NGC 6530	15.5	7 653	6 902	2741	0.47	0.26	bound
NGC 6611	65.0	214 960	1 800	1524	0.01	0.01	unbound
NGC 6823	87.1	424 457	5 151	3274	0.01	0.01	unbound
NGC 6913	19.6	13 182	16 440	5032	0.56	0.28	bound
IC 1805	68.0	238 660	17 689	8369	0.07	0.03	unbound
Tr 1	8.6	1 969	3 585	1210	0.65	0.38	bound
NGC 2571*	14.0	6 009	2 677	1003	0.31	0.14	bound
NGC 7380*	41.0	73 444	1 752	1152	0.02	0.02	unbound
IC 2581*	20.1	13 995	2 324	1287	0.14	0.08	unbound

Notes to TABLE II

Photometric data for open clusters have been taken from Myakutin *et al.* (1984) except for those marked with an asterisk, which have been taken from Piskunov (1983).

ing $\mathscr{M}_*$. (3) The lower value of ϵ_2 may be due to an overestimation of $\mathscr{M}'_{\rm gas}$, which depends upon the mass of the most massive star in the cluster region; it is possible that the most massive star in the cluster region may not be a cluster member. Considering the second most massive star of the cluster as the most massive, the value of ϵ_2 comes out to be 12%. Cohen and Kuhi (1979) have concluded that NGC 2264 has star-formation efficiency $> 10\%$ and Mathieu (1986) has also suggested that NGC 2264 is not a bound cluster.

d) The Average Formation Time of a Bound Cluster

The observed space density of low-mass clouds is higher than the cluster-formation rate, which suggests that either low-mass clouds do not form bound clusters or cluster-formation time per low-mass cloud exceeds 10^8 yr (Elmegreen and Clemens 1985). The observed cluster-formation rate and the density of clouds having masses 10^2–$10^4\,\mathscr{M}_\odot$ show that the ratio τ/f of mean timescale for cluster formation, τ, and the fraction f of the total number of clouds that produce bound clusters is $\sim 10^9$ yr (Elmegreen and Clemens 1985).

If the gas removal time is large, then the clouds having SFEs $\sim 15\%$ may also produce bound clusters. From Tables I and II, we find that there are six clusters which are formed from clouds having masses $\sim 10^4\,\mathscr{M}_\odot$ and it seems that of these at least four are bound clusters. The remaining five, which are unbound clusters, are formed from clouds having masses $\sim 10^5\,\mathscr{M}_\odot$. Thus, it seems that the bound clusters are formed only from low-mass clouds ($\sim 10^4\,\mathscr{M}_\odot$). The model of Elmegreen and Clemens (1985) also suggests that 63% of clouds having mass $\sim 10^4\,\mathscr{M}_\odot$ will produce a bound cluster. Therefore, assuming that at least 50% of the clouds having mass $\sim 10^4\,\mathscr{M}_\odot$ produce a bound cluster, the value of τ comes out to be 5×10^8 yr.

The studies of the Pleiades cluster indicate that star formation in this bound cluster has been a continuous process for about 10^8 yr (Landolt 1979; Stauffer 1980). Herbst and Miller (1982), from the study of NGC 3293, have concluded that star formation in the cluster appears to be a gradual process. The presence of noncoeval star formation in young open clusters, spread over a time of 10^7–10^8 yr, has also been indicated by Sagar (1985). The observed variations in Li abundance among stars in young open clusters also indicate a long timescale for cluster formation (Duncan and Jones 1982). Elmegreen and Clemens (1985) have also concluded that τ may be as large as 10^8 yr. Therefore, it appears that star formation in open clusters is a continuous process that may last at least $\sim 10^8$ yr.

IV. BOUNDARIES OF OPEN CLUSTERS

Kholopov (1969) has concluded that a cluster, from the time of its formation, occupies the volume that is determined by the boundaries of its corona. The corona is inherent in the cluster from the time of its formation and it is not generated by the nucleus but arises simultaneously with the nucleus through the process in which a diffuse cloud is transformed into a star cluster.

If the mass of the cloud which is associated with a cluster and the average absorption of light through the matter of the cloud are known, then with the help of Eq. (1), one can estimate the extent of the open cluster. The mass of the cloud associated with the cluster is estimated by using Eq. (2). The data for this purpose have been taken from Myakutin *et al.* (1984) and Piskunov (1983). We have used $A_v = 3\Delta\,\overline{E(B-V)}$ as the mean absorption in the cluster region. The parameters and results are given in Table III. The estimated statistical error in the determination of radii of the clusters is about 20%. In Table III we have also given the radii of the nucleus of the clusters taken from Lyngå (1987). A comparison of the boundaries of the open clusters obtained in the present work with the sizes of nucleus supports the presence of coronas around the open clusters.

The stability of the corona can be checked using the method of King (1962). The limiting radius of a cluster moving in the general force field of the galaxy is defined as the distance from the cluster center at which the attraction of a given star to the cluster is balanced by the attraction of external masses (Kholopov 1969). For a cluster moving in an elliptical orbit around the Galactic center, the value of the limiting radius r is given by the relation (King 1962)

$$r = R_{\rm p}\,(\mathscr{M}'_*/3.5\,\mathscr{M}_{\rm G})^{1/3},$$

where $R_{\rm p}$ is the perigalactic distance of the cluster and $\mathscr{M}_{\rm G}$ is the mass of the Galaxy. King (1962) has used the above relation in the case of globular clusters, and recently Kontizas (1984) and Kontizas *et al.* (1987) have used the relation to estimate the mass of the star clusters in Magellanic clouds. Assuming that the clusters in the solar neighborhood are moving in circular orbits having radius $R = 10$ kpc and with mass of the Galaxy $\mathscr{M}_{\rm G} \sim 2\times10^{11}\,\mathscr{M}_\odot$, the relation between r and $\mathscr{M}'_*$ is shown in Fig. 2. In this figure we have also plotted the values of $\mathscr{M}'_*$ and radius of the cluster ob-

TABLE III. Estimated boundaries of open clusters.

Cluster	$\Delta\,\overline{E(B-V)}$ (mag)	Mass of gas ($\mathscr{M}_\odot$)	Radius r of cluster (pc)	Radius (pc) (Lyngå 1987a)	Log $\mathscr{M}'_*$ ($\mathscr{M}_L = 0.3(\mathscr{M}_\odot$)
NGC 457	0.14	5 210	13.9	5.4	3.45
NGC 654	0.20	3 829	9.9	1.15	2.84
NGC 2264	0.08	69 180	66.7	2.2	2.85
NGC 2571	0.21	6 009	12.1	4.1	3.00
NGC 6530	0.10	7 653	19.9	3.5	3.44
NGC 6611	0.20	214 960	74.4	2.55	3.18
NGC 6823	0.25	424 457	93.5	6.05	3.52
NGC 6913	0.37	13 182	13.6	1.25	3.70
IC 1805	0.28	238 660	66.3	6.7	3.92
IC 2581	0.31	13 995	15.2	1.95	3.11
Tr 1	0.15	1 969	8.2	1.45	3.08

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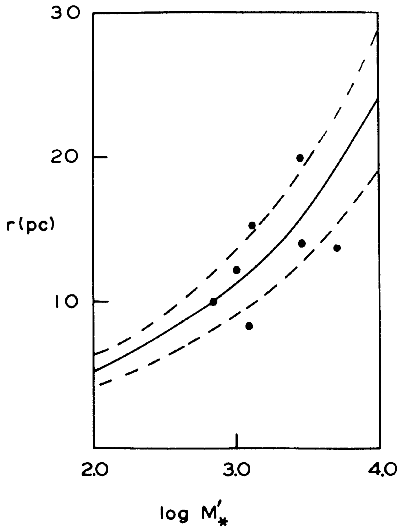

FIG. 2. Relation between radius of the cluster, r, and mass of the cluster, $\mathscr{M}'_*$. The dashed curves represent error of $\pm 20\%$ in r.

tained in the present study. It appears that $\mathscr{M}'_*$ obtained for $\mathscr{M}_L = 0.3\,\mathscr{M}_\odot$ is correlated with the radius of the cluster. However, it is striking to note that unbound clusters do not follow the trend. Lyngå (1987b) and Janes, Tilley, and Lyngå (1988) have concluded that the large diameters at low ages ($\sim 10^7$ yr) correspond to the kinematically unbound clusters akin to OB associations. Mathieu (1986) has shown from direct radial velocity measurements that some well-known very young clusters are in fact unbound and will dissolve in just a few million years.

From Fig. 2 it is concluded that in general the results support the dynamical stability of coronal regions of the bound clusters.

V. SUMMARY

The present study suggests that differential extinction decreases systematically with age of the cluster, and consequently we infer that the average gas removal time must be larger than 10^8 yr.

We have found that of six clusters which are formed from clouds having masses $\sim 10^4\,\mathscr{M}_\odot$, at least four are bound clusters. The five other clouds included in the present study, having initial mass $\sim 10^5\,\mathscr{M}_\odot$, form unbound clusters. Thus we confirm the findings of Elmegreen (1983) that bound clusters are formed in low-mass clouds ($\mathscr{M} \leqslant 10^4\,\mathscr{M}_\odot$) while the unbound OB associations are formed in clouds having higher masses ($\mathscr{M} > 10^5\,\mathscr{M}_\odot$). It is also concluded that if formation of bound clusters takes place only in low-mass clouds ($\mathscr{M} \leqslant 10^4\,\mathscr{M}_\odot$), then the observed low cluster-formation rate and high space density of low-mass clouds suggest that star formation must be a continuous process for about 10^8 yr.

The present work also supports the existence of a corona around open clusters. We have also concluded that the coronal regions in bound open clusters are dynamically stable in the tidal forces of the Galaxy. The coronal regions are formed by regular cluster members and not by the stars that have escaped from the nucleus of the cluster. Thus the presence of corona in star clusters indicates that central condensation of diffuse clouds forms the nucleus while peripheral regions transform into corona of the system.

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