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The Size Distribution of Massive Young Clusters

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Abstract. We have searched the WFPC2/HST archive for data on nearby massive young clusters with low extinction and we have analyzed 27 such objects. A clear dichotomy between objects with a compact core and without it is observed. We attribute this bimodality to the initial conditions of the parent giant molecular clouds and we discuss its implication towards the long-term evolution of the clusters.

1. Description

We have searched the WFPC2/HST archive for data on nearby (within 5 Mpc) massive young ($\lesssim$ 20 Myr) clusters (MYCs) with low extinction ($E(B-V) \lesssim 1.0$ mag). Our goal is to study the structure of a uniform sample of MYCs without the uncertainties induced by including objects located at greater distances (due to the loss of resolution caused by the decrease in angular size) or experiencing large extinctions (which require IR observations). A total of 27 objects are included in our sample.

2. Results

For each of the clusters in the sample we have measured the one-quarter, one-half and three-quarters light radii, $r_{1/4}$, $r_{1/2}$, $r_{3/4}$, using the F336W filter (substituting it with F380W or F439W if an F336W image did not exist) and the integrated magnitude in F555W or F547M. Literature data was used to obtain ages and extinctions; clusters older than $\approx$ 20 Myr were discarded. The distance was then introduced to compute $M_{V,\max}$, the age-corrected (to 4 Myr, the age at which M_V is maximum for a cluster) absolute V magnitude for the remaining 27 clusters. The data is shown in Table 1.

A dichotomy between objects with a core (super star clusters or SSCs) and without it (scaled OB associations or SOBAs) is readily apparent in our images (Fig. 1). Cores are compact ($\lesssim$ 5 pc) structures brighter than any other star by 2 or more magnitudes ($M_{V,\max} \lesssim -10$) while core-less SOBAs extend for several tens of pc. SSC cores are surrounded by a SOBA-like extended halo which can vary from being very weak (e.g. NGC 1569-A) to being more luminous than the core itself (e.g. NGC 4214-I-A or 30 Doradus). An analysis of the ratio $r_{1/2}^2/(r_{1/4}r_{3/4})$ for those SSCs with strong halos reveals that the core and the halo cannot be fitted by a single-component King profile.

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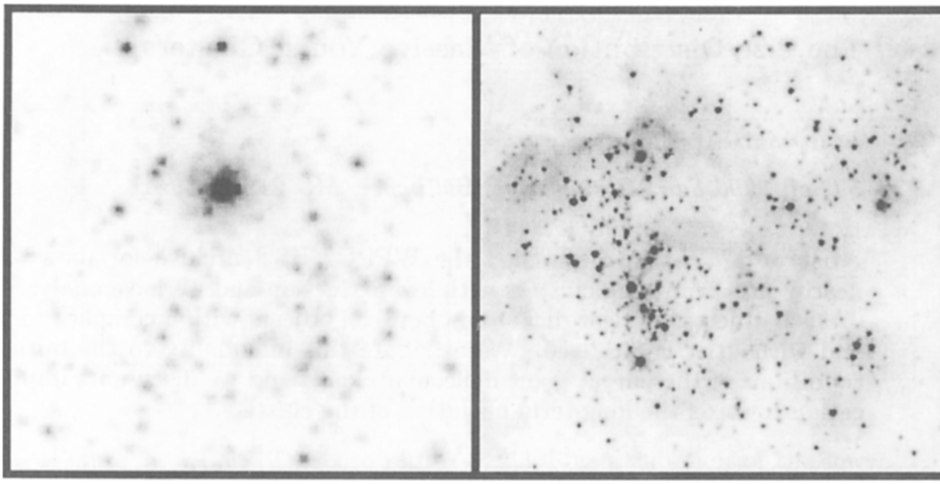

Figure 1. A SSC with a strong halo (NGC 4214-I-A, left) and a SOBA (NGC 604, right). Both fields are 100 pc × 100 pc and were obtained using the WFPC2 F336W filter.

3. Discussion

The clusters in our sample are so young that individual stars (especially those in SOBAs and halos) have not had time to drift far away from their birthplaces, so their positions reflect in good part the original structure of their parent molecular cloud. The two types of structures seen in our sample (compact cores and SOBAs/halos) have a correspondence in the observed morphology of OMC-1 in NH_3 (Wiseman & Ho 1998), where a central core is surrounded by several filaments with smaller cores in them. The same filamentary structure is observed as "chains of stars" in some of the SOBAs and SSC halos studied here.

Several mechanisms can disrupt a cluster in a Hubble time, such as two-body evaporation, tidal shocks, and dynamical friction (Fall 2002). Tidal processes are very effective in disrupting clusters with $r_{1/2} \gtrsim 10$ pc, so SOBAs and the outer parts of SSC halos should disperse in < 10 Gyr. On the other hand, SSC cores (and maybe their inner halos) are expected to become globular clusters, since not only are they compact but also massive (Ho & Filippenko 1996).

We also point out that there are several double cores in our sample, suggesting that two-stage starbursts (Walborn & Parker 1992) may be quite common.

References

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Table 1. Results. Extinctions and ages are calculated from a combination of literature data and an analysis of the nebular structure. $r_{1/4}$, $r_{1/2}$, and $r_{3/4}$ are obtained from the measured angular sizes and the distances. Age-corrected absolute V magnitudes are calculated from the measured apparent V magnitudes and the data in the second to fourth columns.

Cluster	$E(B-V)$ mag	Age Myr	d Mpc	$r_{1/4}$ pc	$r_{1/2}$ pc	$r_{3/4}$ pc	$M_{V,\max}$ mag	Notes
30 Dor	0.35	2.0 ± 1.0	0.05	3.3	9.2	15.5	−12.4	C,St
NGC 595	0.33	4.0 ± 1.0	0.84	14.4	26.9	38.0	−11.4	SOBA
NGC 604	0.20	3.5 ± 0.5	0.84	18.4	28.4	44.3	−12.6	SOBA
I Zw 18-I	0.05	3.5 ± 0.5	10.00	29.1	46.3	75.0	−13.2	SOBA
I Zw 18-II	0.20	3.0 ± 2.0	10.00	27.8	50.4	68.9	−12.3	SOBA
NGC 1569-A	0.55	6.0 ± 4.0	2.20	0.9	2.1	5.3	−14.1	C,Wk,Db
NGC 1569-B	0.55	11.0 ± 3.0	2.20	1.4	3.7	9.5	−14.1	C,Wk
NGC 1569-C	1.00	3.0 ± 2.0	2.20	1.0	2.9	4.2	−12.8	C,Wk,Db
NGC 1705-I-A	0.06	15.0 ± 5.0	5.00	1.5	5.3	20.5	−15.4	C,In,Nb
NGC 1705-I-B	0.06	10.0 ± 8.0	5.00	1.9	2.7	4.9	−11.6	C,In,Nb
NGC 2403-I-A	0.28	6.0 ± 4.0	3.20	11.0	20.6	31.1	−12.6	SOBA
NGC 2403-I-B	0.28	6.0 ± 4.0	3.20	14.8	26.3	33.1	−12.0	SOBA
NGC 2403-I-C	0.28	6.0 ± 4.0	3.20	9.9	19.6	33.4	−11.0	SOBA
NGC 2403-II	0.28	4.5 ± 2.5	3.20	2.0	11.8	27.2	−13.4	C,St
NGC 2403-IV	0.28	4.5 ± 2.5	3.20	9.3	30.0	46.7	−12.7	C,St,Db
NGC 4214-I-A	0.03	3.5 ± 0.5	4.10	2.1	16.5	38.9	−13.7	C,St
NGC 4214-I-B	0.35	3.5 ± 0.5	4.10	21.5	33.0	51.8	−13.6	SOBA
NGC 4214-I-D	0.02	9.0 ± 1.0	4.10	9.9	15.3	27.6	−12.3	SOBA
NGC 4214-II-C	0.20	2.0 ± 1.0	4.10	16.6	21.7	29.2	−11.4	SOBA
NGC 4214-V	0.03	11.5 ± 2.5	4.10	52.5	83.9	127.1	−13.3	SOBA
NGC 4214-VI	0.05	11.0 ± 3.0	4.10	20.9	35.9	58.5	−11.3	SOBA
NGC 4214-VII	0.03	9.5 ± 2.0	4.10	24.8	40.4	56.9	−12.1	SOBA
NGC 4449-N-1	0.25	11.0 ± 3.0	3.90	6.9	16.9	29.3	−15.4	C,St,Nb,El
NGC 4449-N-2	0.25	2.0 ± 1.0	3.90	2.2	5.8	10.6	−13.1	C,St,Nb,El
NGC 5253-I	0.05	11.5 ± 2.5	4.10	2.0	4.0	7.5	−12.4	C,Wk
NGC 5253-IV	0.05	3.5 ± 0.5	4.10	6.2	13.8	19.4	−11.9	C,St,Db
NGC 5253-VI	0.05	11.0 ± 3.0	4.10	1.7	3.1	6.1	−11.3	C,Wk

Notes C: Compact cluster, SOBA: Scaled OB Association
Wk,St: Weak (<40%), Strong (>40%) halo/total ratio
Db, Nb: Double core ($\lesssim$ 7 pc), Nearby ($\lesssim$ 30 pc) cluster present
El: Elongated core

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