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The Disruption Time of Clusters in Different Galaxies

Stratos G. Boutloukos[1,2,3] and Henny J.G.L.M. Lamers[3,4]

[1]*Aristotle University, Thessaloniki, Greece*

[2]*Present adress: University of Tübingen, Institute of Theoretical Astrophysics and Computational Physics, Auf der Morgenstelle 10, D-72076, Germany*

[3]*Astronomical Institute and* [4]*SRON Laboratory for Space Research, Utrecht University, Princetonplein 5, NL-3584CC, Utrecht, the Netherlands*

Abstract.
If the cluster formation rate is constant and the disruption time of clusters depends only on their initial mass as $t_{\rm dis} = t_4 \times (M_{\rm cl}/10^4 M_{\odot})^{\gamma}$, the values of t_4 and γ can be derived in a very simple way from the age and mass histograms of observed clusters. We derived these values from cluster samples in fields of five galaxies: M51, M33, LMC, SMC and the solar neighbourhood. The values of γ are the same in the five galaxies with $<\gamma>= 0.62 \pm 0.03$. However the disruption time t_4 of clusters of 10^4 $M_{\odot}$ is very different in the different locations.

1. The predicted mass and age distributions of observable clusters

Suppose that the disruption time of clusters depends on their initial mass $M_{\rm cl}$ as

$$t_{\rm dis} \ = \ t_4 \times (M_{\rm cl}/10^4 \ M_{\odot})^{\gamma} \qquad (1)$$

where t_4 is the disruption time of a cluster with an initial mass of 10^4 $M_{\odot}$. Suppose that *the formation rate of clusters is constant*, and that the initial mass function of clusters is $N(M_{\rm cl}) \sim M_{\rm cl}^{-\alpha}$, with $\alpha \simeq 2$ (Zhang & Fall 1999). Suppose that clusters fade in a certain wavelength band due to the evolution of their stars as $F_{\lambda} \sim t^{-\zeta}$. Then it is easy to show that both the age and mass distributions of surviving clusters above a certain magnitude limit will consist of double power laws of the type:

$dN_{\rm cl}/dM_{\rm cl} \sim M_{\rm cl}^{(1/\gamma)-\alpha}$ for low mass clusters due to fading
$dN_{\rm cl}/dM_{\rm cl} \sim M_{\rm cl}^{\gamma-\alpha}$ for high mass clusters due to disruption
$dN_{\rm cl}/dt \sim M_{\rm cl}^{\zeta(1-\alpha)}$ for young clusters due to fading
$dN_{\rm cl}/dt \sim M_{\rm cl}^{(1-\alpha)/\gamma}$ for old clusters due to disruption

(see Fig. 1). The vertical shift of the fading line depends on the detection limit of the observations. The horizontal shift of the disruption line depends on t_4.

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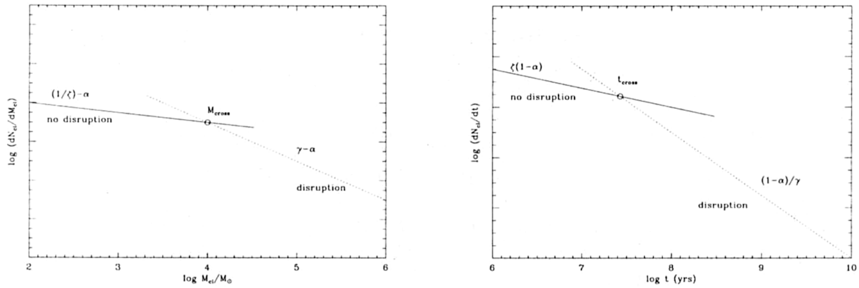

Figure 1. Schematic pictures of the predicted mass distribution (left) and age distribution (right) of clusters due to fading (full lines) and disruption (dotted lines). The y-axes have arbitrary units.

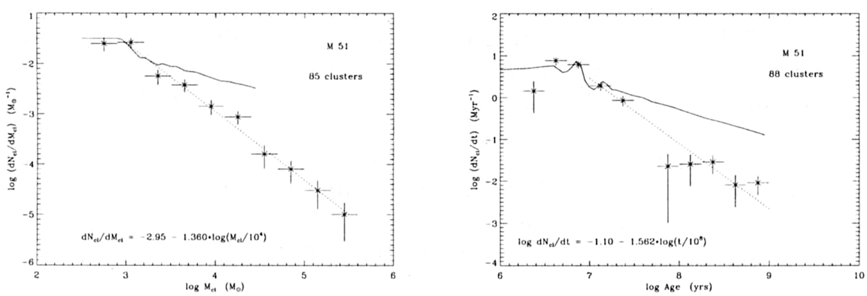

Figure 2. The mass (left) and age (right) distribution of clusters observed with *HST* in the inner 0.8 - 3.1 kpc M51. The full lines is the predicted decrease due to fading (from Starburst99 models). The dashed lines are powerlaw fits for disruption.

The slope of the disruption line depends the value of γ. So both t_4 and γ can be derived from the cluster statistics in a simple straightforward way.

2. Application to different regions

We have applied this method to the samples of clusters observed with *HST* in M51 (Bik et al. 2001) and M33 (Chandar et al. 1999b,c) and to the cluster samples of the LMC and SMC by Hodge (1987, 1988) and of the solar neighbourhood by Wielen (1971). The distributions indeed show the power-law decrease at high mass and/or high age due to disruption (see Fig. 2).

The results are listed in Table 1. The results for the LMC are uncertain because the cluster formation rate may not have been constant (see Da Costa, these proceedings). The values of γ are very similar (within the uncertainties) for the different galaxies with a mean value of $< \gamma > \ = 0.62 \pm 0.03$. The values of t_4, however, are very different for the different galaxies: M51 has the shortest cluster disruption time and the LMC and SMC have the longest disruption times. The difference amounts to about a factor 10^2.

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Table 1. The parameters of the disruption time: $t_{dis} = t_4 \times (M_{cl}/10^4)^{\gamma}$

Galaxy	r_{Gal} kpc	Nr clusters	Age range log (yrs)	Mass range log $M_{\odot}$	$\log t_4$ log (yrs)	γ
M51	0.8 - 3.1	88	6.3 – 9.0	2.6 – 5.6	7.56 ± 0.04	0.64 ± 0.17
M33	0.8 - 5.0	49	6.5 – 10.0	3.6 – 5.6	8.83 ± 0.15	0.72 ± 0.12
MW	7.5 - 9.5	72	7.2 – 10.0	—	9.0 ± 0.3	0.60 ± 0.12
LMC	0 - 5	472	7.8 – 10.6	—	9.7 ± 0.3	0.52 ± 0.06
SMC	0 - 2	314	7.6 – 10.0	—	9.6 ± 0.3	0.61 ± 0.08
					Mean	0.62 ± 0.03

The full study will be described in a series of papers:
a Boutloukos & Lamers (2001): description of method and application
b Lamers, Portegies Zwart & Boutloukos (2001): comparison with disruption simulations
c Lamers & Fall (2001): clusters versus field stars.

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