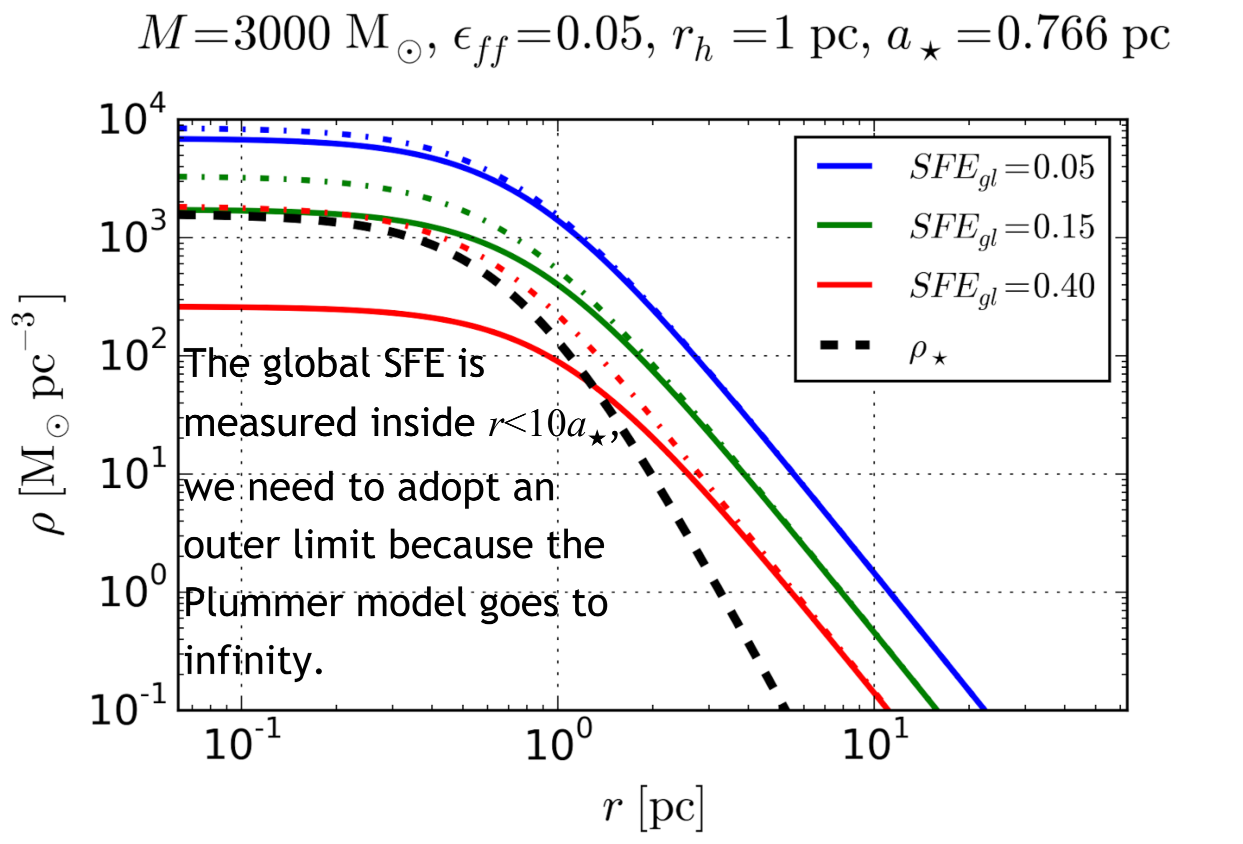
The impact of a SFE profile on the evolution of Open Clusters

Bekdaulet Shukirgaliyev[1,2], Genevieve Parmentier[1], Peter Berczik[1,3,4], Andreas Just[1]

[1]Astronomisches Rechen-Institut, Zentrum für Astronomie, University of Heidelberg, Mönchhofstr. 12-14, 69120 Heidelberg, Germany
[2]Fesenkov Astrophysical Institute, Observatory 23, 050020 Almaty, Kazakhstan
[3]National Astronomical Observatories of China, Chinese Academy of Sciences, 20A Datun Rd., Chaoyang District, 100012, Beijing, China
[4]Main Astronomical Observatory, National Academy of Sciences of Ukraine, 27 Akademika Zabolotnoho St., 03680, Kyiv, Ukraine

ABSTRACT

We study the effect of the instantaneous expulsion of the residual star-forming gas on star clusters wherein the residual gas has a density profile shallower than that of the embedded cluster. This configuration is as expected if star formation proceeds with a given star-formation efficiency per free-fall time in a centrally-concentrated molecular gas clump.
Our model clusters initially have a Plummer profile and are in virial equilibrium with the gravitational potential of the cluster-forming clump. We perform direct N-body simulations whose initial conditions are generated by the program "mkhalo" from the package "falcON" (by W. Dehnen, University of Leicester)
We find that a star cluster with a global SFE less than 15 per cent cannot survive instantaneous gas expulsion and dissolves within a few Myr independently of its stellar mass. If more than 15 per cent of the initial gas mass has been converted into stars at the onset of gas expulsion, the cluster is able to survive more than 100 Myr with its subsequent lifetime in the gravitational field of the Galaxy depending on its initial stellar mass. We therefore conclude that the critical SFE needed to produce a bound cluster is more than 10 per cent smaller than earlier estimates of 33 per cent. This is the consequence of the star cluster having a density profile steeper than that of the residual gas.



Density profiles of: Newly formed **star cluster** (black **dashed** line) corresponds to a Plummer model
Residual gas clump (solid lines)
Initial gas clump (**dash-dotted** lines)

Initial data for N-BODY simulations

Density profile of Star Cluster:

$$\rho_\star(r) = \frac{3M_\star}{4\pi a_\star^3}\left(1+\frac{r^2}{a_\star^2}\right)^{-\frac{5}{2}}$$

Density profile of the residual gas according to Parmentier & Pfalzner (2013):

$$\rho_g = \left(\frac{1}{\sqrt{\rho_\star+\rho_g}}+k\right)^{-2}, \quad k=\sqrt{\frac{8G}{3\pi}}\epsilon_{ff}t_{SF}$$

$$\rho_g = f(\rho_\star(r), t_{SF}), \quad \epsilon_{ff}=0.05$$

Star cluster rotates on a circular orbit at a distance R=8kpc from the Galactic center and with orbital speed V=234.24 km s^{-1}

Stellar evolution is taken into account (SSE)

IMF: M_{low}=0.08 M$_\odot$, M_{up}=100 M$_\odot$ Kroupa(2001)

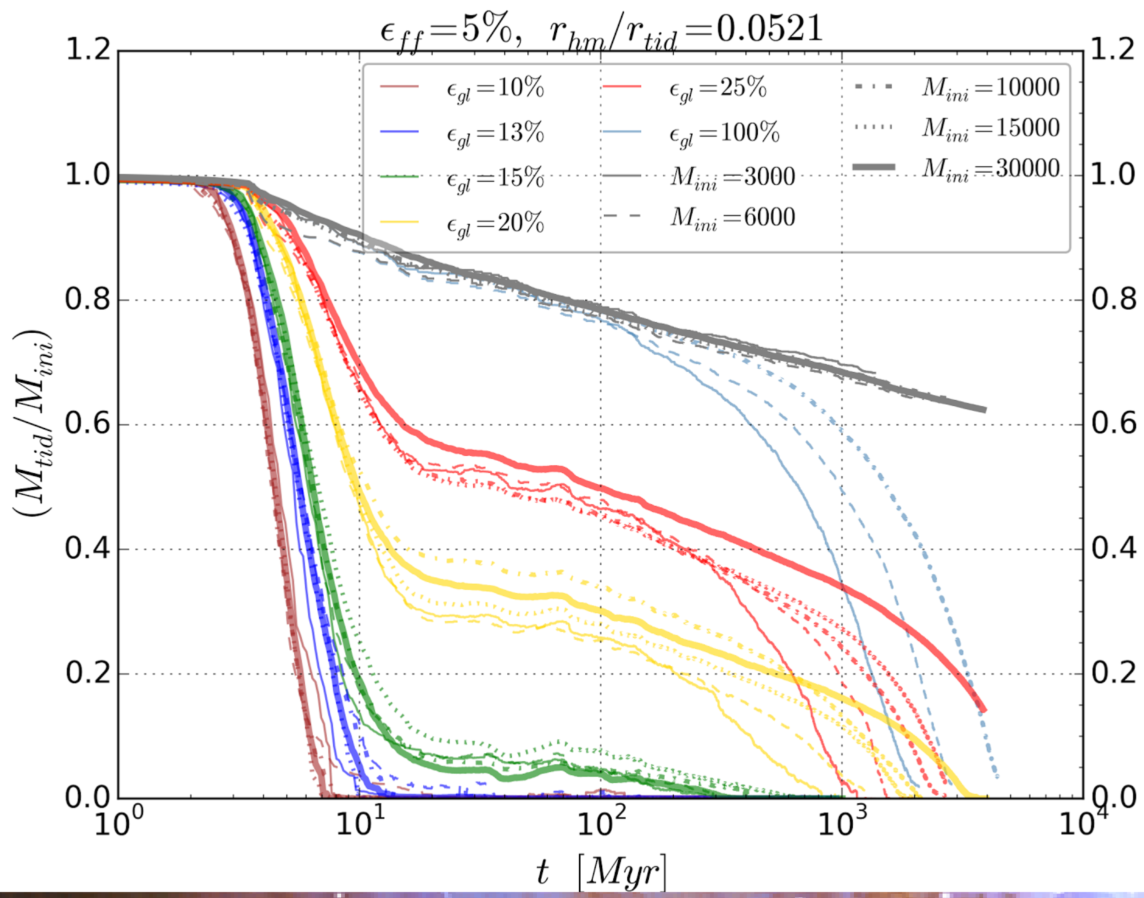
$M_\star$ [$M_\odot$]	$N_\star$	r_{tid} [pc]	r_{half} [pc]	$r_{tot}=10a_\star$ [pc]
3000	5227	19.211	1.00	7.664
6000	10455	24.204	1.26	9.656
10000	17425	28.697	1.49	11.449
15000	26138	32.850	1.71	13.310
30000	52277	41.389	2.15	16.512

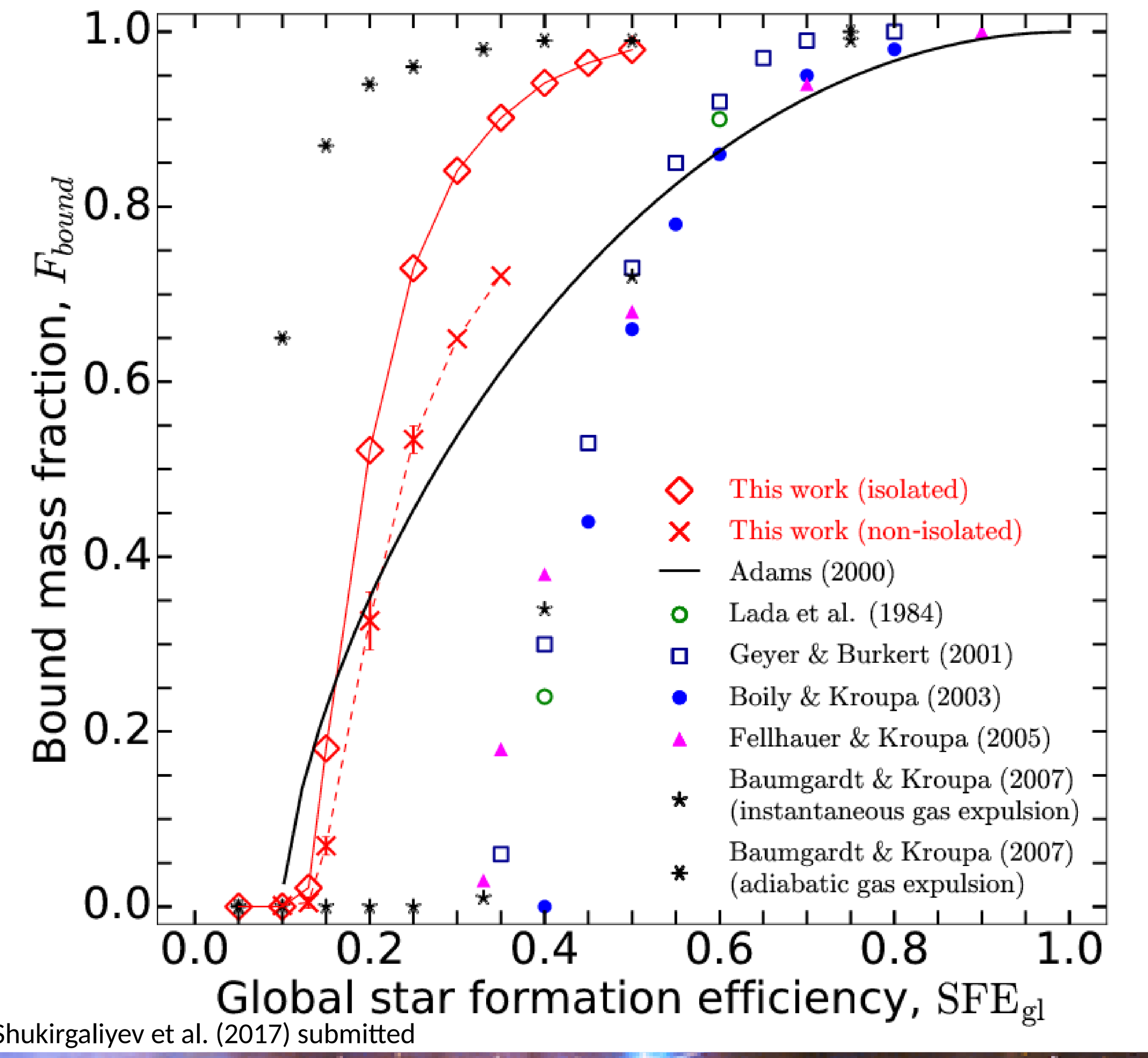
SFE_{gl}	t_{SF} [NB]	t_{SF} [Myr]
5%	2.14	0.39
10%	6.30	1.15
13%	9.58	1.75
15%	12.09	2.21
20%	19.53	3.56
25%	28.74	5.25
30%	39.96	7.29

Star cluster evolution inside the Galaxy

Bound mass fraction defined as the fraction of stellar mass inside the instantaneous tidal radius of the star cluster

The Tidal radius is calculated using Eq.13 from Just et al. (2009)





Shukirgaliyev et al. (2017) submitted

Conclusion

Owing to the star-cluster density profile being steeper than that of the residual star-forming gas, we have improved the Star Cluster Survival Likelihood after Instantaneous gas expulsion compared to most earlier estimates. Our result is reminiscent of that of Adams (2000). However, our work builds on a physical justification for the difference in density profiles between the embedded cluster on the one hand, and the initial and the residual gas on the other hand. This is a consequence of star-formation taking place with a constant star-formation efficiency per free-fall time in a centrally-concentrated gas clump, as described by Parmentier & Pfalzner (2013).

References

1. Adams, ApJ, 542, 964, (2000)
2. Baumgardt & Kroupa, MNRAS, 380, 1589 (2007)
3. Berczik, Nitadori, Zhong et al., In International conference on High Performance Computing, Kyiv, Ukraine, October 8-10, 2011, p. 8-18.
4. Just, Berczik, Petrov, Ernst, MNRAS, 392,969 (2009)
5. Kroupa, MNRAS, 322, 231 (2001)
6. McMillan & Dehnen, MNRAS, 378,541-550 (2007)
7. Parmentier & Pfalzner, A&A, 549, A132 (2013)

Contact: beks@ari.uni-heidelberg.de