Origins: From the Protosun to the First Steps of Life
Proceedings IAU Symposium No. 345, 2018
B. G. Elmegreen, L. Viktor Tóth & M. Güdel, eds.
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doi:10.1017/S1743921319001509

Formation, Initial Evolution and Galactic Dynamic Evolution of Young Star Clusters

Annibal Hetem

Center for Engineering, Modelling and Applied Social Sciences - UFABC,
Rua Santa Adélia, 11111, Santo André, SP, Brazil
email: annibal.hetem@ufabc.edu.br

Abstract. We present an analysis of a sample of clusters of young stars in order to investigate the inherent properties of clustering and dynamic evolution of stellar components, based on fractal statistics. In addition, we present the application of new mathematical and numerical techniques with potentiality for use in models of filamentary structures.

Keywords. stars: pre–main-sequence, ISM: clouds, open clusters and associations: general.

1. Introduction

In previous works, we measured the parameter $\mathcal{Q}$, proposed by Cartwright & Whitworth (2004) for a set of clusters and the results were correlated with other properties of the spatial distributions determined through the King profile and show that almost half of these groups have a relation with the fractal dimension of their parental cloud.

The statistical parameter $\mathcal{Q}$ was measured for the clusters and its correlations with the estimated fractal dimension for the projected near clouds were presented. There are also indications of the presence of substructures similar to those observed in the surrounding clouds. However, other clusters have a radial distribution that does not coincide with the structure of the clouds. These properties may lead to conclusions about the initial conditions of clusters formation (cold collapse or hot collapse), initial evolution (bound or not) and its expected galactic dynamic evolution (crossing time). Figure 1(left) shows the minimal spanning tree, smallest circle and convex hull for NGC 2244, as a visual example of $\mathcal{Q}$ estimation. These studies may give us information about the history of the influence of the Galaxy on clusters and how they were affected by their passage through their structures, as can be seen in Figure 1(right).

2. Genetic Algorithm used to select members of the clusters

In our previous work the dynamical evolution of the clusters was evaluated by Gregorio-Hetem *et al.* (2015) on the basis of the variation of core radius as a function of age for the sample from Santos-Silva & Gregorio-Hetem (2012) compared with σ Ori, Associations and Young Massive Clusters of Milky Way (MW), and clusters of other galaxies of the Local Group (LG) and outside the LG (Portegies Zwart *et al.* 2010). In this poster we presented another method to estimate the membership of the stars in a cluster, based on Bayesian modelling and genetic algorithm by using proper motion provided by the GAIA Data Release 2.

https://doi.org/10.1017/S1743921319001509 Published online by Cambridge University Press

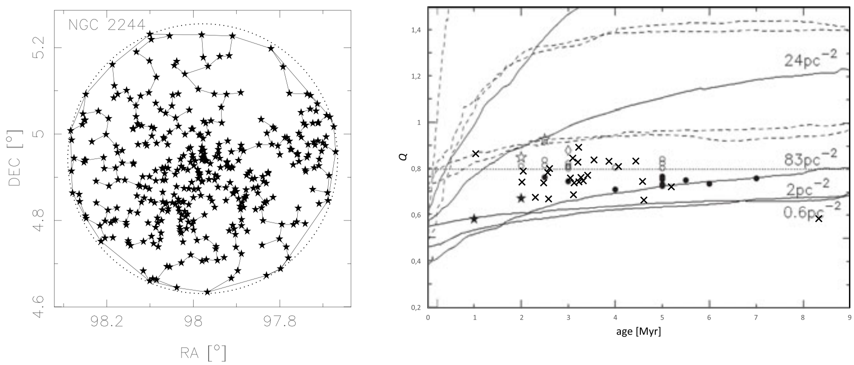

Figure 1. *Left:* Minimal spanning tree, smallest circle and convex hull for NGC 2244. *Right:* Distribution of $\mathcal{Q}$ as a function of age for our sample and other clusters. The results (crosses) are compared to the simulations with feedback (solid lines) and without feedback (dashed lines), indicating the initial densities (number of stars per pc^2) for some of the models adapted from Parker & Dale (2013) and Gregorio-Hetem *et al.* (2015).

3. Estimates of the deviations and error bars

We adopted two methods to estimate the errors associated with the parameter $\mathcal{Q}$. First, the standard deviation was estimated with bootstrapping (Efron 1979), which is independent of model or calculations, is not based on asymptotic results and is simple enough to be automatized. The second method was based on traditional error propagation techniques. The error in a derived measure is obtained straight forward from errors in measurements. It is based on real measurements (observations) and can be implemented in an algorithm if formalism is known.

4. Conclusions

Traditional error propagation techniques can achieve correct estimates of deviations but is strongly dependent on the number of stars. Standard deviation estimated with bootstrapping is independent of number of stars ($\Delta\mathcal{Q} \sim 0.7$), but overestimates deviations for high number of stars (N>200), underestimates deviations for small number of stars (N<100), and gives wrong estimates of deviations for few stars (N<50). Fractal statistics is not indicated to study clusters with 50 stars or less.

Acknowledgements

This work was supported by FAPESP Proc. No. 2017/19458-8 (AH).

References

Cartwright, A., & Whitworth, A. P. 2004, *MNRAS*, 348, 589
Efron, B. 1979, *Bootstrap Methods: Another Look At the Jackknife, The Annals of Statistics*, 7, 126.
Gregorio-Hetem, J., Hetem, A., Santos-Silva, T., & Fernandes, B. 2015, *MNRAS*, 448, 2504
Gower J. C., & Ross G. J. S. 1969, *Appl. Stat.*, 18, 54
Hetem, A. & Lépine, J. R. D. 1993, *A&A*, 270, 451
Megiddo, N. 1983, *SIAM J. Comput.*, 12, 759
Parker, R. J. & Dale, J. E. 2013, *MNRAS*, 432, 986
Portegies Zwart, S. F., McMillan, S. L. W., & Gieles, M., 2010, *ARA&A*, 48, 431
Santos-Silva, T. & Gregorio-Hetem, J. 2012, *A&A* 547, A107

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