Stellar Populations in the Milky Way and Beyond
Proceedings IAU Symposium No. 395, 2026
J. Meléndez, C. Chiappini, R. Schiavon & M. Trevisan, eds.
doi:10.1017/S1743921325000092

Characterizing stellar groups associated with NGC 2659

Jane Gregorio-Hetem[1] **and Annibal Hetem Jr.**[2]

[1]Universidade de São Paulo - IAG/USP,

[2]UFABC Federal University of ABC
email: gregorio-hetem@usp.br

Abstract. In a previous work, we found evidence that part of a sample of Galactic open clusters (OCs) could show subgroups having slight differences on parallax and proper motion, and considerable dispersion of the age estimated for individual cluster members. With the goal of revisiting the analysis of substructures found in the regions containing the clusters, we used astrometric and photometric data from Gaia DR3, aiming to better understand the origin and the evolution of subgroups. This work is dedicated to present the results for NGC 2659, one of the OCs showing two sub-groups.

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

1. Identification of subgroups

This work is motivated by our previous study (Hetem & Gregorio-Hetem 2019) on the fractal structure of a sample containing 50 OCs. Among the most interesting results, we found evidence that some of the OCs could show subgroups having slight differences on parallax and proper motion, and considerable dispersion of the age estimated for individual cluster members. By selecting the best candidates to present subgroups, Gregorio-Hetem & Hetem (2024) revisited the analysis of substructures by using astrometric and photometric data from Gaia DR3 (Gaia Collaboration et al. 2023). In the general context, we aim to better understand the origin and the evolution of subgroups of stars associated with OCs.

The identification of subgroups is based on parallax and proper motion. We adopted Bayesian multi-dimensional analysis and the Cross-Entropy technique to estimate membership probabilities. The distance was obtained from the mean value of distance modes (Luri et al. 2018). An estimation of visual extinction, mass and age of the members of the subgroups is obtained from isochrone's fitting in the M_G versus [BP-RP] diagram. Figure 1 shows evident kinematic differences between NGC 2659a (the main group) and NGC 2659b (secondary group). Members of NGC 2659b are older (∼300 Myr) than NGC 2659a (∼ 30 Myr), while their angular distributions are quite similar.

2. Surface Density Distribution

The fractal analysis is performed to obtain the parameters related to the morphology of the spatial distribution. For the characterization of substructures, we also estimate parameters that are indicator of mass segregation and local surface density, which are also useful to diagnosing the dynamical evolution of the OCs. Figure 2 shows parameters of mass segregation and local surface density estimated on the Minimal Spanning Tree (MST). Mass segregation is found above the limit $\Lambda_{MSR} = 1$. In the right panel of Fig. 2,

© The Author(s), 2026. Published by Cambridge University Press on behalf of The International Astronomical Union.

https://doi.org/10.1017/S1743921325000092 Published online by Cambridge University Press

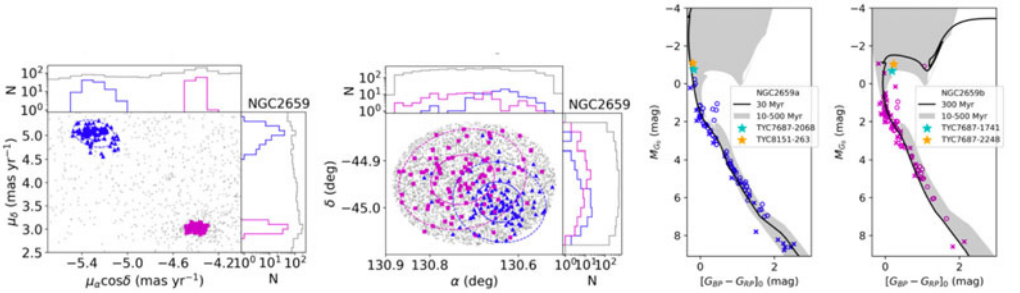


Figure 1. (*Left:*) Vector point diagram of proper motion for all the selected Gaia sources (greydots). Blue and magenta symbols are used for NGC 2659a and NGC 2659b, respectively. (*Middle:*) The projected spatial distribution. (*Right:*) Colourmagnitude diagram for members compared with isochrones from the PARSEC models that best fit the cluster age. Figures extracted from GH24.

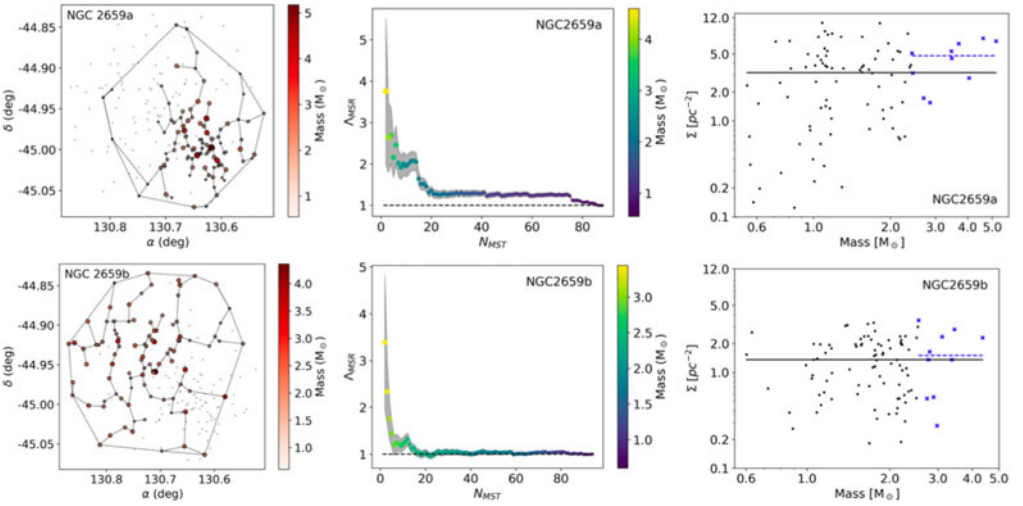


Figure 2. (*Left:*) The MST and convex hull area showing objects with different colours and symbol sizes according to their stellar mass. (*Middle:*) The mass segregation ratio Λ_{MSR} as a function of the number of stars (N_{MST}). (*Right:*) The $\Sigma - m$ plot comparing the local surface density with the stellar mass. The 10 most massive stars are denoted by blue ×. Figures extracted from GH24.

the full line shows the mean value obtained for all the cluster members, and a dashed line is used to indicate the mean value for the 10 most massive stars. NGC 2659a shows mass segregation and higher local surface density when compared to NGC 2659b.

GH24 searched for possible companion groups of NGC 2659 among other OCs reported in the literature as being part of a same group. Giorgi et al. (2023) suggested that UBC 246 (Pismis 9) together with NGC 2659a constitute a double cluster. UBC 246 has a projected position and tangential velocity similar to NGC 2659b. Their distances differ in more than 150 pc (e.g. Cantat-Gaudin et al. 2020; Poggio et al. 2021), but still are within the uncertainties confirming that NGC 2659b is the same cluster previously cataloged as UBC 246. However, the only common characteristic between NGC 2659a and UBC 246 is a similar spatial distribution. Their kinematics and dynamical evolution are not comparable.

https://doi.org/10.1017/S1743921325000092 Published online by Cambridge University Press

Acknowledgements

JGH thanks support from FAPESP (2020/15245-2; 2023/08726-2).

References

Cantat-Gaudin T., Anders F., Castro-Ginardi A. *et al.* 2020, *A&A*, 640, A1
Gaia Collaboration, Vallenari A., Brown, A. G. A., Prusti T. *et al.* 2023, *A&A*, 674, A1
Giorgi E. E., *et al.* 2023, Boletín de la Asociacin Argentina de Astronomía, 64, 90
Gregorio-Hetem J., Hetem A., 2024, *MNRAS*, 533, 1782
Hetem A., Gregorio-Hetem J., 2019, *MNRAS*, 490, 2521
Luri X., Brown A. G. A., Sarro L. M. *et al.* 2018, *A&A*, 616, A9
Poggio E., Drimmel R., Cantat-Gaudin T. *et al.* 2021, *A&A*, 651, A104

https://doi.org/10.1017/S1743921325000092 Published online by Cambridge University Press