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MEMBERSHIP DETERMINATION IN GLOBULAR CLUSTERS WITH GAIA DR2 ASTROMETRY

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RESUMEN

En este trabajo se presenta un método, aún en desarrollo, para identificar posibles miembros de cúmulos globulares con datos del Catálogo de GaiaDR2. El método se basa en un algoritmo de clustering aplicado en un espacio 4D determinado básicamente por las posiciones en el cielo y los movimientos propios. Para confirmar si los agrupamientos encontrados automáticamente por el método corresponden a cúmulos globulares, se analizan los diagramas color-magnitud. Se muestran los resultados obtenidos en algunos cúmulos y se comparan con otros autores.

ABSTRACT

In this work we present a method -still under development- to identify possible members of globular clusters using data from Gaia DR2. The method is based on a clustering algorithm applied on a 4D space that is determined basically by the positions on the sky and the proper motions. In order to confirm that the clusters automatically detected by the method correspond to actual globular clusters, their colour-magnitude diagrams are analysed. We show the results for some clusters and compare them with other authors.

Key Words: astrometry — globular cluster: general — globular clusters: individual: NGC 1261, NGC 3201, NGC 6139, NGC 6362, NGC 6397

1. INTRODUCTION

Since stellar clusters are groups of gravitationally bound stars, their member stars are expected to occupy a rather small volume of space and to share their kinematic properties. Therefore, when space positions and velocities of stars are measured in a region of the sky containing a stellar cluster, field stars (foreground and background) will show a loose distribution while the stars in the cluster will lie in a small region, both in position-space and in velocity-space. Based on these elementary characteristics, most galactic clusters have been primarily detected by an overdensity of the projected positions of stars on the sky, and many methods have been developed to separate members from field stars using proper motions.

In this work we test a method for the detection of members of galactic globular clusters taking profit of the great number of individual stars that have high quality astrometric data in Gaia DR2 (Gaia Collaboration 2018a).

2. METHODOLOGY

Several methods, some of them parametric (Vasilevskis, Klemola & Preston 1958; Sanders 1971) and others non-parametric (Galadi-Enriquez et al. 1998) have been developed and used in the identification of members of stellar clusters, open and globular. Here we develop and test a method that is based on a clustering algorithm in a multi-dimensional space of physical parameters, for instance coordinates, velocities and/or distances. First attempts were done on data from well-known nearby open clusters, with all the Python clustering algorithms codes provided by Scikit-Learn (Pedregosa et al. 2011). The clustering algorithms were tested on different multi-dimensional spaces involving celestial coordinates (α, δ) or their gnomonic projection (X_t, Y_t), proper motions $(\mu_{\alpha*} = \mu_\alpha \cos\delta, \mu_\delta)$ or tangential velocities (Vt_α, Vt_δ), and parallaxes (ϖ) or distances (R) as well as rectangular barycentric coordinates (X, Y, Z).

The method adopted in this work consists of several steps: download Gaia DR2 in a cone around the cluster; compute the gnomonic projection $[X_t, Y_t]$ of celestial coordinates (Astropy Collaboration 2013, 2018); pre-process the data using RobustScaler in Scikit-Learn, in order to remove outliers and normalize the different dimensions; run the BIRCH (Balanced Iterative Reducing and Clustering using Hierarchies) clustering algorithm (Zhang et al. 1996) in the 4-dimensional space $[X_t, Y_t, \mu_{\alpha*}, \mu_\delta]$; fit a 4-dimensional gaussian distribution with the candi-

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TABLE 1

RESULTS OBTAINED FOR EACH CLUSTER, COMPARED TO GC18 AND MWSC RESULTS. ALL PROPER MOTIONS ARE IN MAS/YR

Cluster	This work			GC18			MWSC	
name	# of Members	$\mu_{\alpha*}$	μ_δ	# of Members	$\mu_{\alpha*}$	μ_δ	$\mu_{\alpha*}$	μ_δ
NGC 3201	22200	8.32	-1.96	19921	8.33	-1.99	-4.05	2.10
NGC 6362	12217	-5.54	-4.77	9169	-5.50	-4.74	2.56	0.19
NGC 6397	25112	3.29	-17.58	22116	3.29	-17.59	2.48	-15.41
NGC 6139	2059	-5.90	-2.61	–	–	–	-7.39	-5.73
NGC 1261	2801	1.64	-2.06	–	–	–	-2.38	-6.86

date members of every cluster identified by the algorithm; discard candidate members that lie outside the 3σ ellipsoid and fit a new 4-dimensional gaussian distribution; retain as candidate members of the cluster only the stars within the 3σ ellipsoid of the last fitted gaussian distribution; plot the space distribution, the proper motions vector point diagram (VPD) and the colour-magnitude diagram (CMD) with the members of the clusters found; verify that the space distribution, the VPD and the CMD are consistent with a stellar cluster. The last step is the only one that is performed by a human being.

After removing the members detected by the method we observed residual excesses both in the spatial distribution and in the PM-VPD in some clusters. A deep analysis of those residuals that is not described here for reasons of space, showed that there are members that were not detected by the method just described. Those missing members were subsequently extracted by an ad-hoc procedure and labeled as "possible members" of the cluster.

3. RESULTS

Our first application of this method was the membership determination of variable stars in globular clusters that have been observed or are being observed by us. Therefore, they were our first targets (see the oral contribution "The variable stars of Clement Catalogue in some southern Globular Clusters using Gaia DR2" by Bustos Fierro, I. H. and Calderón, J. H., in this same proceedings).

We found that many globular clusters, those closer than 12kpc, were analysed in a paper by Gaia Collaboration (2018b) - GC18 in Table 1 - and all of them are included in the Catalogue of Milky Way Stellar Clusters - MWSC in Table 1 - by Kharchenko et al. (2013). In that table we compare our results with those previous deteminations.

After the ADeLA meeting, we continued working on the method for extracting members that was improved. The updated version and its application to a larger set of clusters was published in Bustos Fierro & Calderón (2019).

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REFERENCES

Astropy Collaboration 2013, A&A, 558, A33
Astropy Collaboration 2018, AJ, 156, 123
Bustos Fierro, I.H. & Calderón J.H. 2019, MNRAS, 488, 3024
Gaia Collaboration et al. 2018a, A&A, 616, A1
Gaia Collaboration et al. 2018b, A&A, 616, A12
Galadi-Enriquez, D., Jordi, C. & Trullols, E. 1998, A&A, 337, 125
Kharchenko, N. V., Piskunov, A. E., Roeser, S., Schilbach, E., & Scholz, R.-D. 2013, A&A, 558, A53
Pedregosa et al. 2011, Scikit-learn: Machine Learning in Python, Journal of Machine Learning Research 12, 2825
Sanders, W. L. 1971, A&A, 14, 226
Taylor, M. B. 2005, in Astronomical Data Analysis Software and Systems XIV, ed. P. Shopbell, M. Britton, & R. Ebert, ASP Conf. Series, 347, 29
Vasilevskis, S., Klemola, A. & Preston, G. 1958, AJ, 63, 387
Wenger, M. et al. 2000, A&AS, 143, 9
Zhang, T., Ramakrishnan, R. & Livny, M. 1996, BIRCH: An Efficient Data Clustering Method for Very Large Databases. 1996 ACM SIGMOD International Conference on Management of Data, Canada, 4-6 June 1996, 103