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THE OPEN CLUSTER POPULATION AS SEEN BY GAIA

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Abstract. Thanks to Gaia DR2, the science of Open Clusters is revitalised. New memberships are now available for a large number of stars and clusters, fostering the determination of their physical properties and the study of the global properties of the population of Open Clusters in the Galaxy. A biased selection of recent resources and results is presented here.

Keywords: open clusters and associations, Galaxy: structure, Galaxy: kinematics and dynamics

1 Introduction

Positions, parallaxes, proper motions, radial velocities, together with G, B_P and R_P magnitudes delivered in Gaia DR2 (Gaia Collaboration, Brown et al. 2018) made it possible to determine new memberships for an unprecedented number of stars and clusters. Due to their large number of stars sharing the same characteristics, Open Clusters (OCs) were extensively used to validate the Gaia catalogue (Arenou et al. 2018; Katz et al. 2019). They were also used to demonstrate the exceptional potential of Gaia data to revolutionize the field of stellar physics. For instance Gaia Collaboration, Babusiaux et al. (2018) present the composite Hertzsprung-Russell diagram of 32 well known OCs, illustrating how the position of the main sequence, turn-off and giant branches changes as a function of age. Fine structures can be seen and bring new insight into stellar physics. With Gaia, ages and physical properties of OCs can be determined with an unprecedented precision.

Many groups are undertaking studies of OCs with Gaia DR2, for instance to discover new clusters, or to identify tails and evaporating stars, or to get an accurate view of their 3D distribution in the Galaxy and their kinematics. Some recent catalogues and investigations are presented below.

2 New large catalogues of OCs

Cantat-Gaudin et al. (2018) made a systematic search of members around the ∼3300 known OCs, mostly from Dias et al. (2002) and Kharchenko et al. (2013), only based on Gaia DR2 positions, parallaxes and proper motions. Membership probabilities were computed for ∼400 000 stars and the most probable distances were determined for 1229 OCs, including 60 newly discovered objects and two globular clusters previously classified as OCs. The spatial distribution of this sample confirms that young clusters follow the spiral arms while older clusters are found to be more dispersed and at higher altitudes, and are also rarer in the inner regions of the disk.

Soubiran et al. (2018) cross-matched the astrometric catalogue of Cantat-Gaudin et al. (2018) with the radial velocity survey from Gaia DR2 to provide the 6D phase-space information of 861 clusters. They showed that the RVS precision and accuracy is at the level of 0.5 km.s^{-1}. As expected, the vertical distribution of young clusters was found to be very flat, with a dispersion of vertical velocities of 5 km s^{-1}. Clusters older than 1 Gyr were found to span distances to the Galactic plane of up to 1 kpc with a vertical velocity dispersion of 14 km s^{-1}, typical of the thin disc.

Bossini et al. (2019) determined the age, distance modulus and extinction of 269 OCs with a Bayesian tool fitting stellar isochrones on Gaia magnitudes of the high probability member stars from Cantat-Gaudin et al.

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(2018). Other objects, like young clusters, or with high extinction or different metallicities need complementary photometry to deconvolve all the effects.

This three new catalogues form the largest data base of OC parameters derived with homogeneous and high quality data from Gaia DR2 only.

3 New methods for membership determination

A number of methodologies have been developed in the past for the detection of cluster members and sometimes require some adaptation to deal with millions of stars in Gaia DR2 and other large datasets. Cantat-Gaudin et al. (2018) adapted the code UPMASK (Unsupervised Photometric Membership Assignment in Stellar Clusters, Krone-Martins & Moitinho (2014)) to astrometric data. The only physical assumption of UPMASK is that cluster members share common properties and are more tightly distributed on the sky than a random distribution. Olivares et al. (2019) combined Gaia DR2 data and deep photometric observations to make a census of Ruprecht 147 members. They improved the method of Sarro et al. (2014) which models the multidimensional distribution of a cluster field by a Gaussian mixture. Not surprisingly the lists of members differ from one method to another depending on the kind of data considered (astrometry, photometry, radial velocities,..), and on the use or not of observational errors and correlations, and of assumptions. The Bayesian methodology of Olivares et al. (2018) seems promising since it takes into account the full covariance matrix of the observations, which can be of different types and origins, and deals with partially observed objects. However it is still too computationally expensive to deal with millions of stars.

4 New Open Clusters

While Cantat-Gaudin et al. (2018) serendipitously found 60 new OCs which were in the field of known clusters, Castro-Ginard et al. (2018) designed an automated data-mining system for the detection of OCs in Gaia. A density-based clustering algorithm, DBSCAN, finds overdensities and a supervised learning method automatically identifies real OCs. A first run led to 31 new candidates, and another run in the anticentre direction led to 53 new OCs, with about half of them being closer than 2 kpc, suggesting that the census of nearby OCs is not complete. This was also the conclusion of Cantat-Gaudin et al. (2019) who discovered 44 new OCs in the direction of Perseus, using UPMASK. Ferreira et al. (2019) reports the serendipitous discovery of three new open clusters, in the field of the intermediate-age OC NGC 5999 with Gaia DR2 data.

5 Extended structures around Open Clusters

Thanks to Gaia DR2 several groups have explored the surroundings of nearby OCs in order to find escaping members at large distance from the centre. This gives a fantastic opportunity to better understand the dissolution of clusters into the Galactic field. The Hyades being richly populated and the nearest OC in the solar neighbourhood ($\sim$47 pc), it is a benchmark object to make such studies. Röser et al. (2019) used a modified convergent-point method to search Hyades members at large distance from the centre and clearly identified a leading tail extending up to 170 pc and a trailing tail up to 70 pc. Meingast & Alves (2019) selected Hyades members in the 3D galactocentric cylindrical velocity space, thus limited to the brightest Gaia stars having a radial velocity. They identified a S-shape structure of about 200 pc in its largest extent and about 25 pc thick. Both studies are in excellent agreement with theoretical predictions for the tidal tails of the Hyades. With the same modified convergent-point method used for the Hyades, Röser & Schilbach (2019) find the Praesepe's tidal tails extending up to 165 pc from the centre of the cluster. They identify 1393 members, giving a total mass of 794 $M_{\odot}$.

The well-known star cluster Coma Berenices (Melotte 111) has also been the main subject of two studies.Tang et al. (2019) identify leading and trailing tidal tails extending $\sim$50 pc from the cluster center, seven times longer than the cluster tidal radius, $\sim$6.9 pc. This is in good agreement with the findings of Fürnkranz et al. (2019). Both studies report the discovery of a moving group at about 60pc from Coma Ber that looks younger and in an advanced dissolution process.

Ruprecht 147 is an interesting target, being the oldest OC (~2.5 Gyr) in the close solar neighbourhood (~300pc). Yeh et al. (2019) found prominent tidal features aligned with the cluster orbit suggesting that the cluster is undergoing fast dissolution into the Galactic disk.

Another old and popular OC is NGC2682 (M67), the extended halo of which was studied by Carrera et al. (2019b). They find that the cluster extends up to 50 pc, a size twice as large as previously believed.

Tarricq et al. (this volume) have undertaken a systematic analysis of the spatial extent of all the old OCs in a 550pc sphere around the Sun.

6 Chemical composition of Open Clusters

Gaia DR2 does not provide stellar metallicities. However when combining membership and OC parameters deduced from Gaia with ground-based spectroscopic surveys or high resolution studies, mean abundances of OCs can be derived (see for instance Casamiquela et al. in this volume), providing a powerful tool to study the distribution of elements across the Galactic disk. For example Carrera et al. (2019a) cross-matched the OC member lists from Cantat-Gaudin et al. (2018) with APOGEE (Majewski et al. 2017) and GALAH (De Silva et al. 2015) and were able to determine mean abundances for more than 100 OCs, for the first time for 39 of them. While a vertical gradient in metallicity could not be seen, the radial gradient has clearly two regimes, steeper around the solar radius and flatter in the outer disk.

With the final Gaia-ESO catalogue coming soon (Randich et al. 2013) and WEAVE starting observations in 2020 (Dalton et al. 2016), both having dedicated programmes focused on OCs, we will have a huge database to investigate the Galactic abundance gradients and the correlations between chemical composition and kinematics as revealed by OCs.

7 Conclusions

Thanks to Gaia DR2, unprecedented large catalogues of OCs are now available, containing lists of members or mean physical properties, and leading to exciting discoveries. This short presentation of a few examples of OC investigations intended to show how Gaia DR2 is revolutionizing the field. Many other important topics were not mentioned, such as the complex age, spatial and kinematic structure revealed in young OCs. Much more is expected in the coming years with the combination of Gaia and ground based observations, and with Gaia DR3 that will improve the memberships of distant clusters and provide metallicities, even detailed abundances for the brightest stars.

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