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OPEN CLUSTERS AS TRACERS OF THE GALACTIC DISK

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Abstract. Open clusters are good tracers of the properties of the Galactic disk, of its formation, and evolution. There are about 2000 open clusters in catalogues, but we have a measure of age and distance only for about one half of them, and the situation is even worse for metallicity. We are still far from fully exploiting the potentialities of these objects to understand our Galaxy. To this end, the results of the Gaia satellite will be of paramount importance, coupled with complementary and follow-up observations from the ground.

Keywords: Galaxy: disc, Hertzsprung-Russell (HR) diagram, open clusters and associations: general

1 Introduction

Open clusters (OCs) are very useful to describe the properties of the Galactic disk (Friel 1995; Bragaglia & Tosi 2006). Especially in the pre-Gaia* era, their distances and ages are more easily determined than for field stars, except the very near ones. They are useful templates for stellar models at all masses, and are complementary to globular clusters. OCs can be used to describe the metallicity distribution of the disk (e.g., to find gradients and their possible evolution with time). If we wish to use OCs to study the history of the disk we have, of course, to concentrate on the old clusters.

OCs are not the only possibility to study the metallicity distribution. To study the present day distribution we may use H II regions or O/B stars (e.g., Rudolph et al. 2006), or Cepheids, for which the distance is very well defined (e.g., Andrievsky et al. 2004). If we wish to explore the past, we can use samples like the one in the Geneva-Copenhagen survey (Nordström et al. 2004) or planetary nebulae. For the latter there is however controversy on the actual slope of the gradient and on its evolution with time (see e.g., Maciel et al. 2005; Stanghellini & Haywood 2010, for two different views).

A problem, when dealing with field stars, is their migration in the disk (see e.g., Roškar et al. 2008, for a recent paper on the subject): stars may be found at very large distances from their original birth position, and this implies a mixing of the metallicities and a modification/smearing of any gradient. OCs seem more resilient and they generally move much less, so that their present-day Galactocentric distance is a good approximation of the one at birth, as shown in a recent paper by Wu et al. (2009), who calculated the orbits of about 500 OCs.

2 The present situation and the impact of Gaia

There are about 2000 known open clusters (see the catalogue by Dias et al. 2002)†, but information on distance and age is present only for about one half. A measure of metallicity based on several indirect methods is available only for about one tenth of the sample, while metallicity and abundances based on high-resolution spectroscopy for less than about one twentieth. Unfortunately, this wealth of information is not homogeneous, and this has to be kept in mind when studying the properties of the OC sample.

Fig. 1, which uses information from the Dias et al. (2002) catalogue, shows that OCs do not seem to follow an age-metallicity relation: there are old clusters at each metallicity (even if, of course, the sample is small for very old age and very low/high metallicity). It also shows that there is an age dispersion at every Galactocentric

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*The Gaia satellite will derive very high precision parallaxes, proper motions, radial velocities, etc for about 10^9 stars, see `http://www.rssd.esa.int/index.php?project=GAIA&page=index`.

†See web updates at `http://www.astro.iag.usp.br/~wilton`

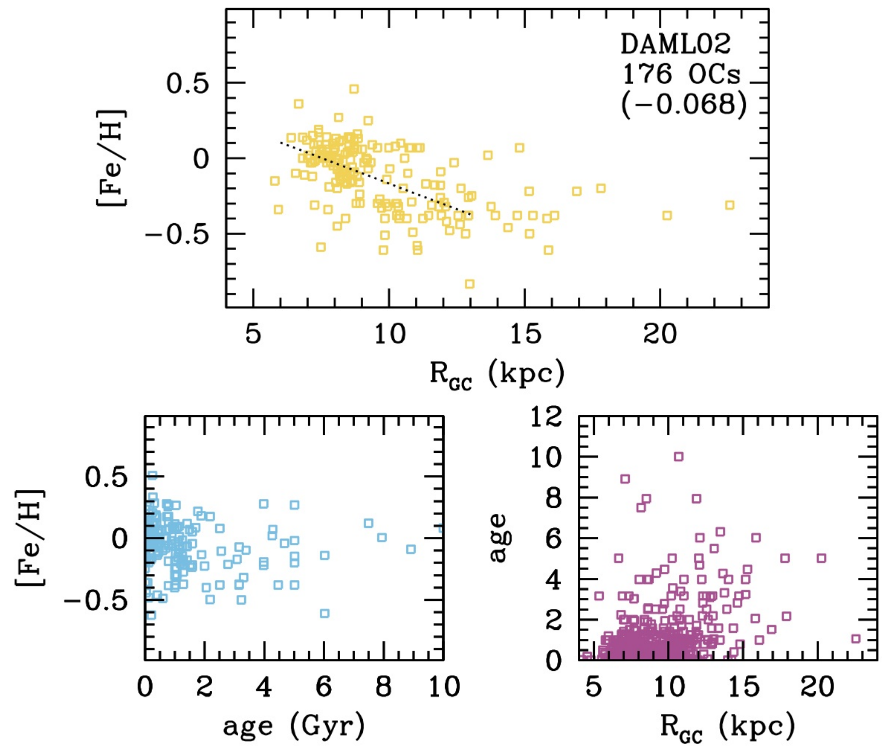

Fig. 1. Using data from Dias et al. (2002), I show here *i*) the metallicity distribution as a function of Galactocentric distance (upper panel), indicating the slope of the metallicity gradient computed in the inner 13 kpc; *ii*) the metallicity distribution as a function of age (lower, left panel), showing that at all ages there is a large spread in metallicity; *iii*) the distribution of age with distance from the Galactic centre (lower, right panel), where we see that old OCs are present in the whole disk.

distance; only old clusters are catalogued at large distances, but this may well be an observational bias. Finally, the figure displays the radial distribution of OC metallicities; there appears to be a decrease in metallicity going towards the outer part of the disk, with a lot of scatter, and maybe a flattening in the outermost region. If we compute a simple linear regression in the 6-13 kpc region, [Fe/H] decreases by about -0.07 dex kpc^{-1}; this interval has been chosen because there seems to be indications that some transition in the metallicity distribution appears near $R_{GC} \sim 13$ kpc (see e.g., Sestito et al. 2008; Carraro et al. 2007; Friel, Jacobson, & Pilachowski 2010). A separation near 10 kpc had been proposed by Twarog, Ashman, & Anthony-Twarog (1997), who thought that OCs presented a step distribution, with inner clusters with [Fe/H]$\simeq 0$ and outer ones with [Fe/H]$\simeq -0.3$ dex; this picture has however been recently challenged by Sale et al. (2010).

While the Dias et al. (2002) catalogue or the WEBDA database (see `http://www.univie.ac.at/webda`) are very useful, we need to consider (sub)samples of OCs analysed in the most homogeneous way to be sure of not missing any details because of systematics between different studies. An example is the BOCCE (Bologna Open Cluster Chemical Evolution) program (see Bragaglia & Tosi 2006; Carretta et al. 2007, and references therein), where deep, precise photometry and high resolution spectroscopy is being obtained for a sample of about 40 OCs, to determine age, distance, reddening, metallicity, and detailed chemical composition. This will, for instance, give strong constraints to models of Galactic chemical evolution. Fig. 2 illustrates what is already possible to do. There are about 70 old OCs for which the metallicity has been derived using high resolution spectroscopy by many different groups. Using these [Fe/H] values and the most recent and reliable distances and ages, we may build the radial metallicity distribution at different epochs and this can be compared with results of chemical evolution models. But recall that this sample is not homogeneous and that distances (and ages) are still rather poorly constrained.

The Gaia space mission, which will fly in the next years, will produce data of unprecedented precision also for the OC sample, providing in particular individual distances and proper motions for all cluster stars brighter than about V=20. Radial velocities, metallicities and abundances will only be obtained for the brightest objects.

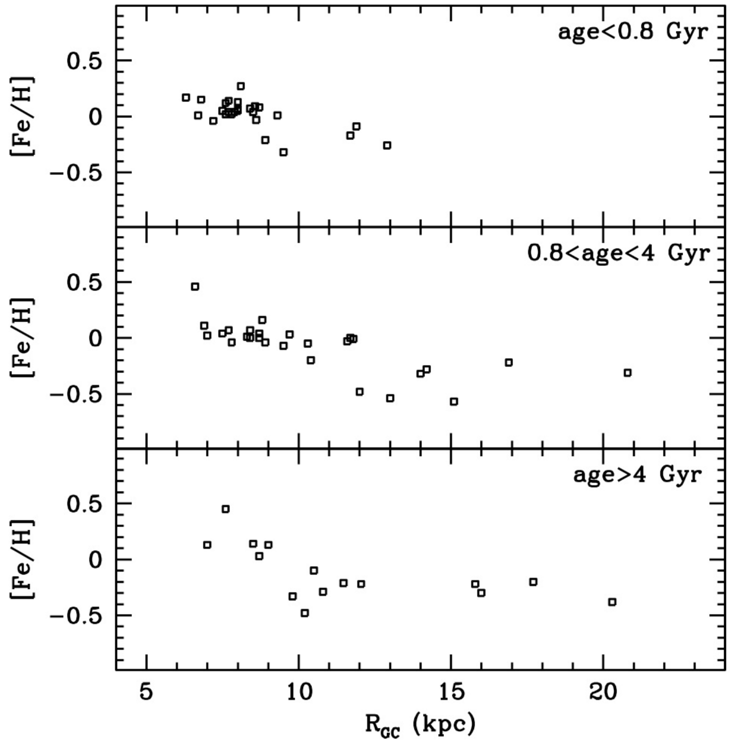

Fig. 2. Radial distribution of metallicity for the about 70 OCs with [Fe/H] derived using high-resolution spectroscopy, divided in three age intervals. The oldest clusters seem to define a steeper slope, especially if we limit to the inner 12-13 kpc.

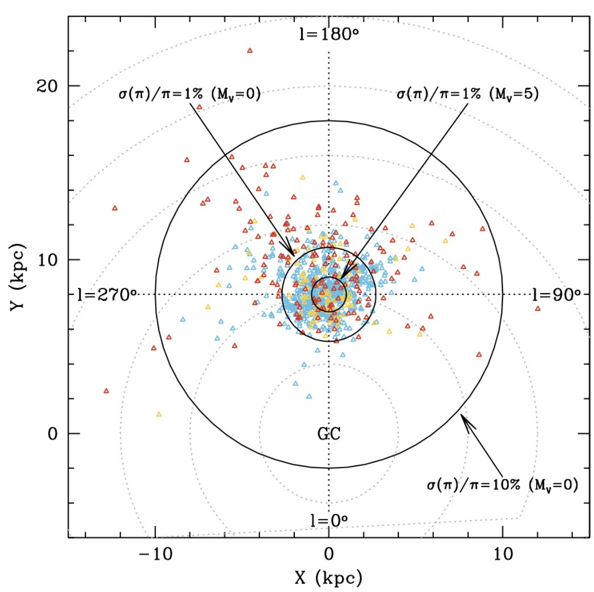

Fig. 3. Distribution of the known OCs in the Galactic plane; the Galactic centre is at (0,0), the Sun at (0,8) kpc. The OCs are indicated with light blue, yellow, and red symbols for young, intermediate-age, and old clusters, respectively. Also indicated are the approximate regions for which the Gaia distances will be more precise than 1% for main sequence and giant stars, and 10% for giants.

Fig. 3 shows what will be the impact of Gaia on the measured distances: for almost the entire OC family, a precision in distance better than 10 % for the individual star, hence much better for the cluster as a whole, will be reached, at least for giant stars (the brightest ones in the old OCs useful to study the history of the disk). An even higher precision will be reached by proper motions, permitting a clear-cut separation of cluster members from field stars, a very difficult task in most instances with the present data.

3 Wish list

To fulfill the promise of understanding the formation and evolution of the Galactic disk using open clusters we need:

- Large samples of OC, with a full coverage in position, age, and metallicity;
- To add undiscovered/unstudied clusters;
- To obtain precise, deep photometry (wide/narrow band and IR) on wide fields;
- Information on membership (from proper motion or radial velocity)
- Information on binary fraction and, possibly, on individual binaries;
- Spectroscopy, at resolution from about 10000 (for radial velocity) to 50000 (abundances) of large, significant samples of stars in each OC;
- Up-to-date stellar models and conversions to the observational plane;
- Using the maximum homogeneity in observations and analysis.

Part of these will be provided by Gaia, but coordinated ground based efforts are required, together with some advances in stellar modeling and precise and homogeneous studies.

I wish to thank the organizers of the "Resolved stellar populations" Workshop for the opportunity to talk about open clusters. Special thanks go to all people collaborating with me on this subject. I have made ample use of the WEBDA, originally created by J.-C. Mermilliod and presently maintained by E. Paunzen.

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