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The Bologna Open Clusters Chemical Evolution project (in short: BOCCE)

A. Bragaglia

INAF – Osservatorio Astronomico di Bologna, via Ranzani 1, 40127 Bologna, Italy
e-mail: angela.bragaglia@oabo.inaf.it

Abstract. I present here our project, the Bologna Open Clusters Chemical Evolution (BOCCE) project, aimed at using Open Clusters as tracers of the disk properties and their evolution with time. We are collecting and homogeneously analyzing data, both photometric and spectroscopic, on a large sample of open clusters, representative of the old cluster population, and I show here results obtained on a subset of our clusters.

Key words. Galaxy: disk – Galaxy: open clusters – Galaxy: abundances

1. Introduction

Galactic open clusters (OCs) are considered very good tracers of the disk' properties: they are seen over the whole disk, cover the entire age interval of the disk and trace its chemical abundances both at present time and in the past (e.g., Friel 1995).

One of the subjects where there are several advantages in using OCs instead of isolated, field stars, is the study of the disk metallicity distribution and its possible evolution with time. As a matter of fact, the distances and ages of OCs can be measured with higher precision up to large distances, and their ages span a much larger interval than e.g., B stars, Cepheids or Planetary Nebulae, other widely used tracers.

OCs are also useful tests for stellar models and are complementary to older, metal-poorer globular clusters.

If we want to study the history of the disk, we have to obtain information on a large and significant number of OCs; of course, old OCs must be conspicuously present in this sample. With our program BOCCE, that stands for Bologna Open Cluster Chemical Evolution project, we are building and homogeneously analyzing such a sample; for a a detailed description of its goals and a summary of results on the first part of the photometric work, see Bragaglia & Tosi (2006).

Very briefly, we employ i) deep, precise photometry to derive ages, distances and reddeninigs (and a first indication of the metallicity) using the comparison of observed and synthetic colour-magnitude diagrams (CMDs, e.g. Bragaglia & Tosi 2006); ii) medium resolution spectra to derive radial velocities and crucial information on membership (e.g., D'Orazi et al. 2006); iii) and high resolution spetra to derive the metallicity and the detailed abundances (e.g., Carretta et al. 2004, 2005).

We try to cover all disk positions both in distance and direction, as shown in Fig. 1, where we plot all the OCs for which photometry has been acquired. We concentrated on old

Send offprint requests to: A. Bragaglia

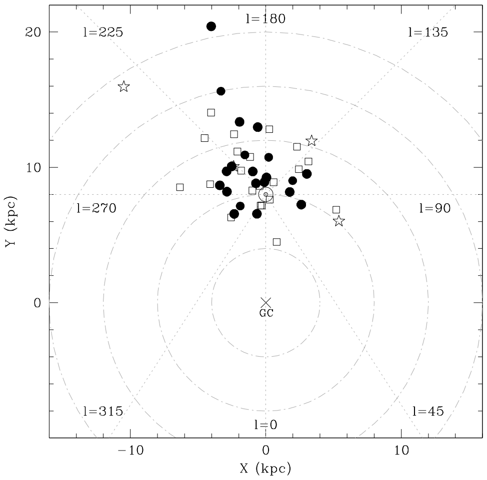

Fig. 1. Positions of the clusters in the BOCCE sample; filled symbols indicate objects for which the photometric analysis is completed, stars indicate work in progress, and empty squares clusters acquired but not studied yet.

clusters and have already published results for 16 OCs older than about 1 Gyr, while a few more are expected soon. This number represents a fair fraction of the total number of similar, known clusters: in the most recent catalogue by Dias et al. (2002) there are about 120 OCs older than 1 Gyr, out of the more than 1700 objects present.

We have already obtained large amounts of data, but the analysis has been completed only for part of them. Furthermore, we also plan to increase our sample including interesting clusters from the archives or from collaborations, and homogenizing their analysis to our system. An example of the latter will be the distant OCs observed with FLAMES/UVES (PI S. Randich) in the anticenter direction (see e.g., Sestito et al. 2006 and Sestito et al. this conference).

1.1. Photometric data

We have alredy published results for 20 clusters (Bragaglia & Tosi 2006; Bragaglia et al. 2006a,b; Tosi et al. 2007), which represent about one half of our sample and that cover the age range from about 0.1 to 9 Gyr. We are presently adding other ones, like Be 20 and Be 66 (Andreuzzi, Bragaglia & Tosi 2007), or NGC 6791.

The homogeneous determination of ages, distances, reddening and a first indication of metal abundance is our main result. They are derived using the photometric data and synthetic CMDs based on stellar evolutionary tracks and taking into account photometric errors and completeness, and the presence of a fraction of binaries. We always use the same three sets of tracks: the FRANEC, without overshooting (Dominguez et al. 1999), the old Padova ones, with classical overshooting (e.g., Bressan et al. 1993), and the FST ones, which use the Full Spectrum Turbulence approach described by Ventura et al. (1998).

Once we have completed our homogeneous analysis for a large enough number of targets, we can compare the clusters' properties on a common scale, and so derive information on the Galactic disk; and we may compare the influence of different assumptions on the measured parameters, and test stellar models. Since we derive all parameters with the three sets, we have a good estimate of the systematics involved.

We have a few very interesting objects in our sample. In particular, we have observed Berkeley 29 (Tosi et al. 2004), the farthest known cluster, very important to define any metallicity gradient, and Berkeley 17 (Bragaglia et al. 2006b), which is perhaps the oldest known open cluster, with an age similar to the one of the youngest globular clusters. We are presently working on the photometry of NGC 6791, a rather peculiar cluster, that could be the oldest (but see Be 17) and metal-richest (but see NGC 6253) in our Galaxy. We use the deep and precise data obtained with the CFHT (Kalirai et al. 2007), taking also into account information on membership from radial velocities, very useful to better define its red giant branch. We have just started the simulations of its CMDs, but its very high metallicity is an obstacle, since of the models that we homogeneously use, only the Padova tracks reach the required Z. We need new, more metal-rich extension of the two other sets (in preparation).

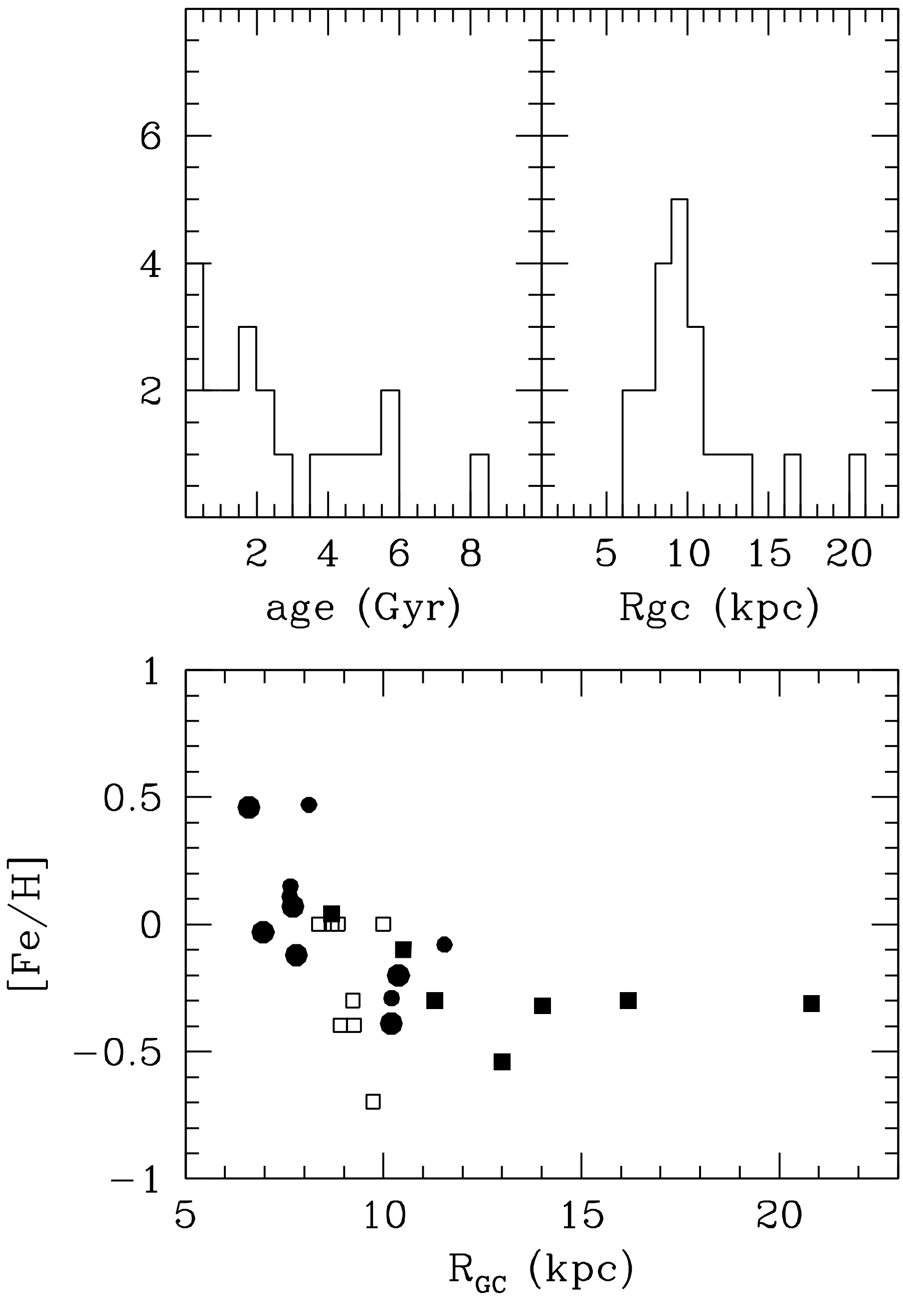

Fig. 2. Upper panels: histograms of the ages and distances fron the Galactic center for BOCCE clusters. Lower panel: the radial abundance distribution. Different symbols indicate the degree of integration in the BOCCE sample: large filled circles: all parameters obtained in the BOCCE system; smaller filled circles: [Fe/H] obtained in BOCCE, R_{GC} from literature; filled squares [Fe/H] from literature, R_{GC} in BOCCE; squares: R_{GC} in BOCCE, but [Fe/H] from literature (filled) or from the BOCCE photometry, i.e., from the Z of the evolutionary tracks (open), respectively.

1.2. Spectroscopic data

We have already analyzed the high-resolution spectra of about 10 clusters (Bragaglia et al. 2001; Carretta et al. 2004, 2005; Gratton et al. 2006; Carretta et al. 2007), which span the metallicity from [Fe/H] $\simeq -0.5$ to [Fe/H] $\simeq +0.5$ dex. We already have data on a few more objects, and have recently obtained observing time to complete the spectroscopic part of other OCs for which the photometry has been presented. Further data will be added, from the archives and from a companion program, for other interesting clusters.

Also in this case, our goal is to reach the highest possible precision and homogeneity. To ensure this, we always use the same model grids to derive abundances, the same line lists, gf's, solar reference abundances, and the same method of measurement of EWs or synthetic spectra.

All our spectra have been obtained up to now with SARG@TNG, FEROS@1.5m ESO, and UVES@VLT; they have a resolution $R \sim 30000 - 50000$. Our strategy is to obtain spectra of a few stars (3-5) in each cluster, chosen among confirmed members by previous radial velocity or proper motion studies. We usually concentrate on red clump giants, since they are the best compromise between the bright luminosity necessary to reach very good S/N even at high resolution and temperatures not too cold to be a problem for the analysis of line-crowded spectra.

One of the motivation of our project is to determine the metallicity distribution in the Galactic disk. We have not reached our goal yet, but first results can be seen in Fig. 2. The upper panels show the distributions in age and distance from the Galactic center of all cluster already photometrically analyzed. The lower panel is a representation of the radial metallicity distribution. However, this plot is not completely based on BOCCE, because the analysis is done completely by our group on a common scale only for part of the clusters. At the moment we cannot yet derive a self-consistent picture of the radial metallicity distribution or of its possible evolution with time: we need to reach full homogeneity.

One may wonder whether OCs really are good tracers of the Galactic disk. When we compare their abundances (or better the run of elemental ratios with [Fe/H]) with those of field stars, the answer seems to be positive. In general the elemental ratios follow the same pattern for OCs and field stars. There are a few exceptions, like Na; this could mean for instance that we are not taking into account well the non-LTE effects for Na, or maybe that there are actual differences between giants (usually used to study clusters) and dwarfs (usually selected in field samples). This is a complicate subject and needs dedicate studies.

An example of "good" behavior comes from the α-elements: they share the same run with metallicity for field and cluster stars, in all the metallicity range covered by OCs. Furthermore, the [α/Fe] ratios do not show any dependence from the cluster age, in our sample or in literature ones. There is an indication of a slight trend for [α/Fe] values to increase with Galactocentric distance; however, this is based on literature abundances, and seems not confirmed by other studies (see Sestito et al., this conference). Further discussion is postponed until we have homogeneously analyzed all the BOCCE sample.

2. Summary

To briefly summarize :

- we are studying (old) open clusters as tracers of the disk properties;
- to this end we are deriving ages, distances, reddenings, metallicities and detailed abundances for a large sample of old OCs (about 20 already analyzed photometrically, and about 10 spectroscopically, up to now);
- in doing so, we try to maintain the maximum homogeneity of methodology, to reach really sound and significant results;
- if we compare them to field stars, the open clusters do indeed appear to be good tracers of the general disk abundances, confirming that we may use them to trace the disk properties;
- abundances of open and globular clusters and field stars studied by our group will be

on a common scale, ensuring meaningful comparisons between different stellar populations;
- finally, our sample can be used to test stellar evoutionary models of different ages and metallicities, being complementary to the older, metal-poorer globular clusters.

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