Asociación Argentina de Astronomía
BAAA, Vol. 53, 2010
J.J. Clariá, M.V. Alonso, A.E. Piatti & F.A. Bareilles, eds.

PRESENTACIÓN ORAL

The Galactic open cluster system: evidence of enhanced formation episodes

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Abstract. The exciting debate about the existence of signs of enhanced formation of Galactic open clusters (OCs) is revisited here on the basis of a revised age distribution. By using the recently updated 2009 version of the Dias et al. catalogue of 1787 OCs, we found that the present OC's age distribution presents two primary excesses at $t \sim$ 10-15 Myr and 1.5 Gyr. We interpret both excesses as signs of enhanced formation episodes similar to those that occurred in other galaxies (e.g., M 51, NGC 1705). When restricting the OC sample to those located in the solar neighbourhood, with the aim of avoiding incompleteness effects, we also find that these clusters are engraved with clear signs of enhanced formation at both ages.

Resumen. A partir de la distribución revisada de las edades de los cúmulos abiertos, presentamos resultados acerca del apasionante debate sobre la existencia de importantes episodios de formacion de cúmulos abiertos en nuestra Galaxia. Las edades analizadas fueron tomadas del catalogo recientemente actualizado (febrero 2009) de 1787 cúmulos abiertos compilado por Dias et al. Encontramos que la actual distribución de edades de los cúmulos abiertos presenta dos excesos primarios de cúmulos centrados en 15x10^6 años y 1.5x10^9 años, respectivamente, los cuales interpretamos como signos de intensos episodios de formación similares a los ocurridos en otras galaxias (por ejemplo, M51, NGC 1705). Cuando restringimos la muestra de cúmulos a aquéllos ubicados en la vecindad solar, con el proposito de evitar efectos de incompletitud, encontramos que dichos cúmulos también están marcados con signos claros de intensos episodios de formación alrededor de ambas edades.

Age distribution of Galactic open clusters

Janes & Phelps (1994), Bonatto et al. (2006, hereafter BKBS), and Wu et al. (2009, hereafter WZMD), among others, have examined the open cluster's age distribution. They have found open clusters (OCs) with ages spanning the range $\sim$ 1 Myr - 9 Gyr with two typical timescales that resemble the timescales of the thin and thick Galactic disks. BKBS found this result from a thorough study of the properties of the Galactic disk based on 654 OCs distributed within a region of ~ 5 kpc from the Sun, using the WEBDA[1] database. On the other hand, WZMD employed a recently updated version (February 2009) of the Dias et al. OC catalogue (2002). This catalogue provides information on the fundamental parameters for 1787 objects and includes the previous catalogues of Lyngå (1987) and Mermilliod (1995 in the WEBDA database). New objects and data that were not present in the previous catalogues have now been included in this one. However, from an astrophysical point of view, the number of OCs with age estimates are nearly the same in both studies.

In general, the histograms of the OC's age distribution have been built using a fixed age interval. BKBS used a bin size of 200 Myr over the whole age range ($\Delta t \sim 9$ Gyr). However, with an age interval of 200 Myr, it is impossible to distinguish the intrinsic fluctuations in the OC's age distribution during the past 100 Myr, which are seen in bin sizes of ~ 10 Myr. On the other hand, employing bin sizes of 200 Myr results in a nearly subsampled OC's age distribution for ages over ~ 4 Gyr. The large difference among the ages of OCs led WZMD to vary the age intervals and use bin sizes of 100 Myr for OCs younger than 1 Gyr and 500 Myr for OCs older than 1 Gyr.

We also produced OC's age histograms using the updated version[2] of the Dias et al. OC catalogue (2002) and age intervals of 50 Myr, 100 Myr, 200 Myr, and 500 Myr, respectively. In each histogram we found peculiar features not seen in the remaining ones. These examples show that a fixed age bin size is not appropriate for yielding the intrinsic age distribution, since the result depends on the chosen age interval. A more robust age interval should be the one whose width is a measure of the age errors of the clusters in that interval. This would lead to the choice of very narrow age bins for young clusters and relatively broader bins for the older ones.

With the aim of building an age histogram that tightly reproduces the intrinsic OC's age distribution, we take the uncertainties in the age estimates into account to define the age intervals in the whole OC age range. Thus, we produce a more appropriate sampling of the OCs per age interval than is built using a fixed bin size, since we include in each bin a number of clusters whose age errors are close to the size of this bin. Indeed, the age errors for very young OCs are a couple of Myrs, while those for the oldest OCs are at least of a few Gyrs. Therefore, smaller bins are apropriate for young clusters, whereas larger bins are suitable for the old ones. We then searched the literature to find that typical age errors are $0.10 \lesssim \Delta\log(t) \lesssim 0.20$. Therefore, we produced a revised age histogram by setting the bin sizes according to this logarithmic law, which traces the variation in the derived age uncertainties in terms of the OC ages. We used intervals of $\Delta\log(t) = 0.20$, but a slightly noisy histogram would be obtained if we used $\Delta\log(t) = 0.10$. The subdivision of the whole age range in age intervals of different sizes can be performed on a observational-based foundation, since they are a measure of the typical OC age errors for each age range. Figure 1 shows the resulting age histogram compared to those by BKBS and WZMD. We also included the error bars produced by a Poisson statistics. As can be

[1]http://obswww.unige.ch/webda

[2]February 2009; http://www.astro.iag.usp.br/$\sim$wilton

seen, we can unveil fiducial characteristics of the OC's formation history during the past tens of Myr, and appropriately group the older ones as well.

Figure 1 depicts a close-up view at the younger ages along with an integral picture of the older ones, thus spanning the whole age range in detail. The close-up panel reveals an important excess of OCs at $\sim$ 10-15 Myr, which curiously arises after a period (30 Myr $\lesssim t \lesssim$ 100 Myr) of decreasing OC formation, overtaking the previously simple picture that 2/3 of the known OCs were born during the last 100 Myr (WZMD). The figure also presents very interesting features. Firstly, there is an abrupt jump at $\sim$ 1.5 Gyr, which largely doubles the number of older OCs counted in the adjacent bin, and continues with a relatively steady OC formation rate for the adjacent younger bins (300 Myr $\lesssim t \lesssim$ 1500 Myr). The relatively wide age interval at the jump bin ($t \sim$ 1.0 - 1.5 Gyr) reflects the size of the age errors at that age, rather than a measure of the duration of the burst or triggered OC formation process. Secondly, this noticeably increased level in the number of OCs seems to keep up on average until the last hundred Myr, when a change in the slope of the histogram takes place ($t \sim$ 100 Myr). Both primary excesses ($t \sim$ 10-15 Myr and 1.5 Gyr) are signs of enhanced formation episodes, similar to the bursting cluster formation events occurring in other galaxies.

With the aim of confirming a bursting-like OC formation process in the Milky Way (MW) in contrast to a closed-box scenario where the OC formation is at a constant rate, we compared the cumulative age distribution of the Galactic OCs with those of star clusters in the unperturbed spiral galaxy NGC 4395 (Mora et al. 2009) and in M 51, which shows vestiges of star cluster bursts (Hwang & Lee 2009). The result is depicted in Figure 2, wherein we normalized the age distributions for comparison purposes. The comparison is strictly valid for clusters younger than $\sim$ 1 Gyr, which is the range observed by Mora et al. (2009) and Hwang & Lee (2009). As can be seen, the cumulative OC age distribution is more like that of M 51 than NGC 4395. Therefore, we conclude that the OC formation rate in the Milky Way has been enhanced during its lifetime.

We recall that much more work is needed to confirm whether the enhanced OC formation would have taken place across the entire MW disk, more concentrated in the Galactic centre, more concentrated in the outer parts of the MW disk, or even azimuthaly uniform. Other questions still remain, as whether the enhanced OC formation were triggered by interaction with the MCs (McClure-Griffiths et al. 2008, Shattow & Loeb 2009), accretion of a dwarf satellite galaxy (Frinchaboy et al. 2004), infall of high-velocity gas clouds (Lockman et al. 2008), etc.

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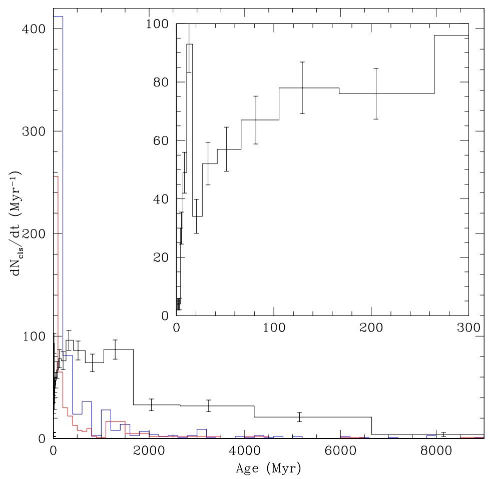

Figure 1. OC's age histograms obtained by BKBS (2006), WZMD (2009) and by us represented with blue, red, and black solid lines, respectively. An enlarged view in also included.

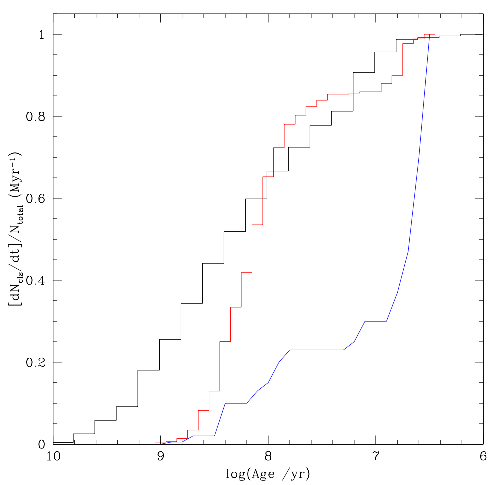

Figure 2. Normalized cumulative age distribution for Galactic OCs (black line), and star clusters in M 51 (red) and NGC 4395, blue solid line.

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