# GLOBULAR CLUSTERS IN BLUE COMPACT GALAXIES AS TRACERS OF THE STARBURST HISTORY

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**Abstract.**
Representing single stellar populations, globular clusters (GCs) are relatively easy to model, thus providing powerful tools for studying the evolution of galaxies. This has been demonstrated for the blue compact galaxy ESO338-IG04. GC systems in galaxies may be fossils of starbursts and mergers. Thus studies of GCs in the local universe may add to our understanding of the formation and evolution of galaxies and the distant universe.

## 1. Introduction – Globular cluster formation and destruction

Globular clusters (GCs) are in general old stellar systems with masses $10^4$ to $10^7 M\odot$, and are believed to be among the first ingredients to form in the process of galaxy formation. Thus understanding how GCs form is vital for understanding how galaxies form. Extragalactic GC systems in e.g. elliptical (E) galaxies often have bimodal colour distributions, indicating the presence of populations with different metallicity and/or age. Studies of merging galaxies, e.g. the "Antennae" (Whitmore and Schweizer 1995) and NGC 7252 (Miller et al. 1997), have shown that these often contain young GC candidates in great numbers. These galaxies are believed to evolve into E galaxies as the merger remnants relax. The GC candidates in the more evolved mergers have redder colours indicating higher ages. Very young so-called "super star clusters" (SSCs) have been found in many starburst galaxies, including dwarfs (e.g. Meurer et al. 1995). The SSCs have properties which largely agree with those expected for young GCs, although the masses are quite uncertain, and are probably younger examples of the objects seen in the mergers. The triggering mechanism for the starbursts in the dwarfs that host SSCs is still an open question, but dwarf mergers are not ruled out. SSCs have also been found in the centres and circum-nuclear rings in giant barred spirals (e.g. Barth et al. 1995 and Kristen et al. 1997)

In conclusion young globular cluster candidates are found in extreme and energetic environments indicating that they can only be formed under special conditions. The coeval formation of many GCs will require extreme conditions, e.g. very high pressures and gas densities (Elmegreen and Efremov, 1997), conditions which are fulfilled in mergers. Moreover, bars trigger gas flows and nuclear rings may be created by dynamical resonances, enhancing the density. A newly formed GC will not automatically become an old GC (like the ones in our Galaxy) as time goes by, but faces the risk of destruction and dissolution. Their ability to survive depends on their interaction with their environment, but also on their IMF. A galactic bar for instance is not a favourable place for GC survival since strong shocks will easily disrupt many young GCs. The conditions in mergers, and in particular dwarf galaxies may be more favourable for GC survival.

## 2. Young and old GCs in ESO 338-IG04

ESO338-IG04 is a blue compact galaxy (BCG). A BCG is characterised by compact appearance and HII region like spectra indicating high star formation rates, and in general low chemical abundances. Most BCGs are dwarf galaxies that, for some reason, presently are undergoing starbursts. HST/WFPC2 images reveals that ESO338-IG04 hosts a very rich population of compact star clusters counting more than one hundred objects (Östlin et al. 1998). The centre is crowded with young SSCs, but in addition lots of intermediate age and old objects are found outside the starburst region (there might well be some in the centre as well but they drown in the light from young SSCs). Photometric modelling (using Salpeter and Miller-Scalo IMFs) indicates masses in the range $10^4$ to more than $10^7 M\odot$ and a wide range of ages, from a few Myr up to 10 Gyr (see Fig 1). The spread in ages is real and not caused by observational errors. Moreover, there are groupings in the age distribution indicating that the cluster formation history has not been continuous. Most apparent is of course the numerous very young and luminous SSCs, but perhaps even more interesting is the presence of one or two populations of massive GCs with age 2 to 5 Gyr. This population, when corrected for objects below the detection limit, shows that starburst progenitor had a specific frequency $S_N$ (a measure of the number of GCs relative to the host galaxy luminosity) comparable to those of giant Es. In addition there are old ($\geq$ 10 Gyr) and 0.5 Gyr GCs present. Follow up spectroscopy of two GC candidates in ESO338-IG04 confirms the the results from photometry (Östlin et al. 1998c, in preparation).

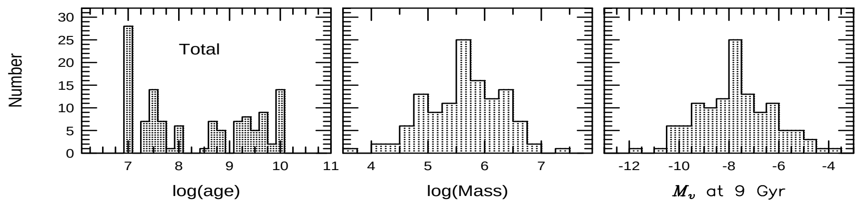


*Figure 1.* Modelled ages (left), masses (middle) and absolute V magnitudes when transforming all objects to an age of 9 Gyr (right). The results are based on a standard Salpeter IMF, but are very similar for a Miller-Scalo IMF (Östlin et al. 1998a).

The dynamics and morphology of this galaxy indicates that a dwarf merger is responsible for the starburst (Östlin et al. 1998a, 1998b). Thus we have a splendid low luminosity ($M_B = -19$) counterpart of the giant mergers mentioned above. Even if young GCs of course may disrupt or dissolve, the presence of intermediate age GCs proves that GC formation is not a phenomenon that was isolated to the very earliest days of galaxy formation. SSCs are often found in BCGs which suggest that they might be a good laboratory for studying GC formation; and a closer look for aged GCs may provide important information on previous bursts.

## 3. GCs as starburst fossils

We have seen that objects which are likely to be young GCs have been found in galaxies which are starbursts and/or mergers. The presence of intermediate age GCs in ESO338-IG04 and somewhat aged objects in the merger remnants suggest that at least a considerable fraction of young GCs will survive. It is a general property of starbursts to reveal the presence of SSCs when studied at high spatial resolution. R136, the central cluster in 30 Dor., may *perhaps* be the closest example of a GC in the making. Even if not all SSCs become GCs, we can conclude that all newly formed GCs must have properties similar to SSCs. Moreover the coeval formation of many massive GCs would produce a starburst in itself. Let us illustrate this in a figure (Fig 2): A starburst leads to SSCs of which at least a fraction becomes GCs, and the reverse is also true, although SSCs may form also in bars, which however are hostile environments. Therefore the age distribution of the GC population can be used to infer the SSC, and thus starburst, history. It is also clear that mergers are capable of trigger starbursts, but we do not know yet if a merger is required for the occurrence of a global starburst in a galaxy. If that would be the case, GC populations could be used to trace the merger history of galaxies. Of course, the question marks in Fig. 2 must

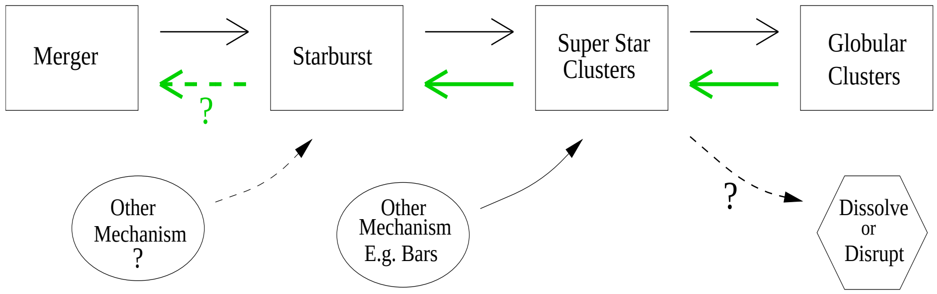


*Figure 2.* A sketch of the connection between GCs, SSCs, starbursts and mergers

be straightened out before GCs can be used as general probes.

Although GCs provide information on the starbursts history of galaxies, they do not necessarily tell us about the overall star formation history, afterall GC free galaxies exist. There is obviously two different modes of star formation: the "violent" starburst mode which favours cluster formation and the "quiet" mode that may still produce the bulk of the field stars in most galaxies (Van den Bergh 1998). In nearby galaxies the star formation history (SFH) of the field population can be studied through deep colour magnitude diagrams (cf. Tolstoy this volume). In most galaxies however one has to infer the overall SFH from the integrated stellar population. A GC is much easier to model because it represents a true single coeval (on the scale of a few Myrs) stellar population. Spectroscopy can be used to investigate metallicities to circumvent the age-metallicity degeneracy. Thus GCs can serve as excellent probes for unveiling the starburst history in moderately distant galaxies. But also a more complete picture of the GC content in local galaxies would provide important information. This might be of importance for interpreting deep surveys which often are biased towards starburst galaxies. Depending on how strong the connection to mergers will prove to be, GC populations may also be useful for studying the morphological and number evolution of the galaxy population.

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