Globular Cluster System evolution in early type galaxies

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Summary. Globular clusters (GCs) constitute a system which is evolving because of various interactions with the galactic environment. Evolution may be the explanation of many observed features of Globular Cluster Systems (GCSs); the different radial distribution of the GCS and the stellar component of early type galaxies is explained by dynamical friction and tidal effects, this latter acting both on the large scale (that of the bulge-halo stars) and on the small scale (that of the nucleus, often containing a central massive black hole). Merging of quickly orbitally decayed massive GCs leads to formation of a Super Star Cluster (SSC) which enriches the galactic nucleus and is a reservoir of mass-energy for a centrally located black hole.

1 Introduction

The Hubble Space Telescope and large ground based telescopes are providing a continuously increasing amount of data concerning GCSs in galaxies, mainly of the early types, since the pioneering work [17].

Two are the most debated points: (i) the difference in the GCS and galaxy light spatial distribution, and, (ii) the existence of a bimodal color distribution for GCSs, and the possible differences between the blue and the red population. The two points are, likely, related; in any case, here I will not discuss about point (ii) (see the recent [22] paper) but just about point (i) which is better observationally stated and deserves a correct interpretation.

2 The GCS and stellar radial distributions in galaxies

It is nowadays clear that the majority of galaxies shows a radial profile of their GCS shallower than that of the stars toward the galactic center. Ellipticals show a more or less peaked stellar profile toward the galactic center (actually, many have a ‘cuspy’ profile), while the GCS radial distribution has, usually, a core. The related literature is so vast that we limit to recall [13], [12]. The explanation of this difference in terms of formation and evolution of elliptical galaxies (see [11], [12], [3], [1]), or in terms of evolution of the GCS itself (see [1], [13], [11]) is still debated.
The interpretation on the basis of GCS evolution is more appealing, because much simpler and not based on qualitative and arbitrary modelizations of GC formation in galaxies (remember the Occam’s razor...). Moreover, it has other important astrophysical implications.

Why is it simple? Because it is based just on the, conservative, assumption that the GCS and the halo-bulge galactic stars are coeval and had initially the same spatial distribution; the presently observed difference can be caused by evolution of the GCS. That GCSs in galaxies undergo to evolution is undoubtful, because they are evolving aggregates of stars moving in an external potential which influences the system also by tidal distortion and by dynamical friction. A detailed analysis of the GCS radial profile evolution in early type galaxies has been presented in [10] where a convincing explanation of the observed comparative features of GCS and stellar light profiles is given.

Some researchers have invoked one observational feature, the GCS radial distribution being shallower for brighter galaxies than for faint [12], as evidence against the ‘evolutionary’ explanation. Apart from that the claimed correlation is not universal (for instance, [2] found a quite shallow GCS radial distribution in the Virgo dE VCC 1087), the evolution of a GCS due to the combined role of dynamical friction, acting on the large scale, and nuclear tidal distortion, on a smaller scale, leads to a correlation between the slope of the GCS radial profile and the galaxy integrated luminosity exactly as observed (see Fig. 1 left panel). This because of the existing correlation between the two scales through the positive galaxy mass-central black hole (BH) mass in galaxies. As example of observational output of the large (GCS core radius) and small (BH tidal destruction radius) scale-correlation see right panel of Fig. 1. In conclusion, the GCS slope vs. galaxy luminosity correlation is not, unfortunately, a way to distinguish between the two above mentioned hypotheses (compare left panel of Fig. 1 with Fig. 4 in [3]).

3 Super star cluster formation and nucleus accretion

There is growing evidence of the presence of very massive young clusters, as extensively discussed in this Conference, up to the extremely large mass of W3 in NGC 7252 ($M = 8 \pm 2 \times 10^7$ $M_\odot$ [19]). Massive clusters are not an insignificant fraction of the GCs in galaxies; on the contrary, [16] indicates how up to a 40% of the total mass in the GCS of brightest cluster galaxies is contributed by massive GCs (p.d. mass $> 1.5 \times 10^6$ $M_\odot$), in good agreement with recent theoretical results by [18].

The initial presence of massive clusters in a galaxy makes particularly intriguing the GCS evolutionary frame sketched in Sect.2, for the presence of some massive primordial clusters may have had very important consequences on the initial evolution of the parent galaxy. Actually, the GCS evolution in an elliptical galaxy naturally suggests the following scenario:

(i) massive GCs on box orbits (in triaxial galaxies) or on low angular momentum orbits (in axisymmetric galaxies) lose their orbital energy rather quickly;

(ii) after $\sim 500$ Myr many GCs, sufficiently robust to tidal deformation, are limited to move in the inner galactic region where they merge and form an SSC;

(iii) stars of the SSC buzz around the nucleus where some of them are captured by a BH sitting there, partly increasing the BH mass;
(iv) part of the energy extracted from the SSC gravitational field goes into e.m. radiation inducing a high nuclear luminosity up to AGN levels.

Point (i) has been carefully studied in [23] and [11] in self consistent models of triaxial core-galaxies, and presently under study in triaxial cuspy-galaxies with dark matter halo [3]; the validity of point (ii) has been demonstrated by first results of [4], while the resistance to galactic tidal forces of sufficiently compact GCs confirmed by [20] and the actual formation of an SSC via orbitally decayed cluster merger has been proved by detailed N-body simulations [7], [21]. Points (iii) and (iv) deserve a deeper investigation by mean of accurate modeling, even if they seem reasonably well supported by previous studies [4], [6].

4 Conclusions

Various papers by our research group have shown that many of the observed GCS features find a natural explanation in terms of evolution of a GCS in the galactic field, assuming the (very conservative) hypothesis it was initially radially distributed as the galactic stellar component and coeval to it. In other words, no ad hoc assumptions are needed to explain, for instance, the difference, observed in many galaxies, among the GCS-halo star profiles. The initial presence of some massive GCs ($M \geq 5 \times 10^6 M_\odot$) lead to the formation of a central SSC via merger of these orbitally decayed massive clusters. The SSC mix it up with the galactic nucleus in which is embedded and constituted a mass reservoir to fuel and accrete a massive object therein. Observationally, this latter picture is supported by the observed positive correlation between the estimated quantity of mass lost by a GCS in galaxies and the mass of their central BHs (see Fig. 1 in [5]). On the theoretical side, the modes of mass accretion onto the BH via star capture from the merged SSC still remain to be carefully investigated.

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Fig. 1. Left panel: GCS core radius as a function of the absolute integrated V mag. of the parent galaxy. Dots refer to data in [12], with their best fit as dashed line. Solid lines are two evolutionary models, with two different initial value of the GCS core radius (see Fig. 3 in [10]). Right panel: time evolution of the core radius of the GCS in a triaxial galaxy containing a central BH of mass (from bottom up) $10^7$, $10^8$, $10^9$ $M_\odot$ (Fig. 6 in [9]).

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