The Nuclear Structure of the Sagittarius Dwarf Spheroidal Galaxy

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**Abstract.** We present a study of the central parts of the Sagittarius dwarf spheroidal galaxy (Sgr). We found a clear overdensity of Sgr’s stars around M 54 (hereafter NS). NS is well represented by a King model and it has the characteristics of a typical dwarf elliptical nucleus. Whether this means that M 54 has spiraled into the potential well of NS or that M 54 is the real nucleus and NS has formed into its potential wells, remains an open question to be addressed.

1. **Introduction**

Dwarf galaxies are considered the building blocks of the hierarchical merging process which is thought to be the fundamental mechanism for the formation of large galaxies. Among dwarf galaxies, dwarf ellipticals are the most common type of galaxy in the nearby universe (Ferguson & Binggeli 1994, hereafter FB94). Hence, the comprehension of their structural and evolutionary characteristics is a major task of modern cosmology.

A characteristic of many dE is an enhancement of the surface brightness in a small central region, called nucleus (N). Such feature defines the sub-class of nucleated dwarf elliptical (dE,N). The observed nuclei have surface brightness profiles similar to globular clusters, they seem to share with globulars the same general surface brightness - absolute magnitude relation and their luminosity function overlaps the luminosity range covered by globular clusters (FB94,
Hence, the origin of dE,N nuclei is generally reconduced to two possible mechanisms, both related with massive star cluster: i.e. (a) the decay of the orbit of a pre-existing globular toward the tip of the galactic potential well, driven by dynamical friction, or (b) the \textit{in situ} formation of a giant cluster from gas fallen to the center of the galaxy (see Durrell 1997 and references therein). It has also been suggested that the capture hypothesis is more appealing to explain faint nuclei, while the brightest ones may be better understood within the second scenario. dE nuclei may be also related with the Ultracompact Dwarf Galaxies (UCD) recently discovered in the Fornax cluster (Drinkwater et al. 2003). In summary, the phenomenon of dE nucleation is far from being well understood and it is subject of continuous investigation (see, e.g. Stiavelli et al. (2001) and references therein). A local example would certainly provide a deeper insight of the phenomenon, but the only acclaimed case in the Local Group is M 32, a companion of the Andromeda galaxy whose stellar content may be studied in some detail only with HST (Grillmair et al. 1996).

On the other hand, the Sagittarius dwarf spheroidal galaxy (Sgr) (Ibata et al. 1994) is the most nearby Galactic satellite and since its discovery many authors suggested and discussed the hypothesis that the associated massive globular cluster M 54 is the nucleus of Sgr (Sarajedini & Layden 1995, Bassino & Muzzio 1995, Layden & Sarajedini 2000, hereafter LS00). If the presently observed Sgr dSph is the relic of a previous dE,N it may provide an excellent local testbed to study the nucleation process. Hence the detailed study of its inner regions may have valuable spin-offs in this field.

2. The nuclear structure

It is well known that the Sgr galaxy hosts a composite stellar population with stars spanning a pretty large range of ages (from $< 1$ to $> 10$ Gyr) and metallicities (from $[\text{Fe/H}] < -1.5$ to $[\text{Fe/H}] \simeq 0.0$) (Monaco et al. 2002, hereafter Pap-I, LS00, Monaco et al. 2003, Bellazzini et al. 1999a,b). However its stellar content is dominated by a quite metal-rich population ($[M/H] \simeq -0.4/ -0.6$) with an age of $\sim 4-6$ Gyr (LS00, Pap-I). As a consequence, the color-magnitude diagram (CMD) of Sgr shows the typical features of an old metal-rich population with a clearly defined Red Clump of He-burning stars and a cool Red Giant Branch (RGB). On the other hand M 54 is a quite old and metal poor globular cluster (LS00) with an extended blue Horizontal Branch and a steep RGB. Therefore, the evolved stars of the two systems may be easily discriminated on the CMD to study the respective spatial distributions.

In Pap-I we presented a large photometric database containing position and photometry of $\sim 490,000$ sources down to $V \sim 23$ in a $1 \times 1$ deg$^2$ field centered on M 54. From this sample we selected, on the basis of the CMD morphology, stars representative of M 54 and of the Sgr dominant population from the Pap-I database.

Both selected samples are composed only of RGB stars and have the same limiting magnitude. Hence, according to the evolutionary flux theory (Renzini & Fusi Pecci 1988) they approximately trace the same fraction of the total light of each system. For both samples we computed the star counts density profile. Since star counts are proportional to luminosity (Renzini & Fusi Pecci 1988), we
The nucleus of Sgr

Figure 1. Left hand panel: Radial surface brightness profile obtained from a sample of M 54 (triangles) and Sgr (circles) stars. The continuous line is the sum of a King model having the structural parameters of M 54 (Trager et al. 1995) plus a constant component. Right hand panels: The observed profile of Sgr is fitted by the sum of a King model plus a constant component. A good match is achieved in the right panel where we used a tidal radius larger than the one of M 54.

We can convert the projected star density (N/area) into the surface brightness: \( \mu_V = -2.5 \times \log(N/\text{area}) + c \) where the value of the constant \( c \) is obtained by fitting the radial profile of M 54 with a King model (King 1962, using the structural parameters tabulated in Trager et al. 1995) and normalizing the central surface brightness to the value reported in the literature, \( \mu_{V,0} = 14.75 \text{ mag/arcsec}^2 \).

The obtained surface brightness radial profiles are plotted on the left panel of Figure 1, as well as the model used to obtain the normalization. It can be appreciated that the model is a pretty good representation of the profile of M 54 (assuming that the difference at \( r < 15'' \) from the center of M 54 are due to incompleteness effect). As can be seen, also the Sgr's sample shows a quite sharp central structure (hereafter NS).

We estimate the integrated magnitude of NS to be \(-10.01 \lesssim M_V \lesssim -8.2\), and the surface brightness of Sgr at the core radius of the main body to be \( \mu_{V,c} \approx 26 \text{ mag/arcsec}^2 \) (using the model computed by Majewski et al. 2003). These values place NS exactly in the locus occupied by dE,N in Figure 1 of Drinkwater et al. (2003) (Surface brightness of the envelope vs Core luminosity).

Is M 54 or NS the nucleus of Sgr? Are M 54 and NS part of the same structure? As can be seen in the right panels of Figure 1, a good match of the NS surface brightness profile can only be obtained with a King model having a tidal radius larger than the one of M 54. A Kolmogorov-Smirnov test confirms that the two distributions are incompatible each other. We conclude that M 54 and NS do not share the same radial profile. Moreover M 54 is a metal poor Globular Cluster and its integrated colors are bluer than the Sgr field, while Galactic nuclei usually have colors similar to that of the surrounding galaxy field (FB94), even if a few nuclei bluer than the field do exist (Durrell 1997). On the other hand,
of course, NS has the same color of the surrounding galaxy. Moreover, if M 54 is the nucleus of Sgr, the difference in the central surface brightness of the nucleus with respect to the main body is \( \Delta \mu_{V,0}^{Sgr-M 54} \approx 10.25 \text{ mag/arcsec}^2 \), while none of the 5 dE,N analysed by Geha et al. (2002) and at most one of the 14 analysed by Stiavelli et al. (2001) show such a large difference. A lower \( \Delta \mu_{V,0}^{Sgr-NS} \) value, more typical of dE,N, value is obtained for NS.

It is thus safe to conclude that NS shows the typical characteristics of a galactic nucleus, while the same statement does not apply to M 54.

While M 54 is generally considered the nucleus of Sgr, we now suggest the possibility that NS is the actual nucleus of Sgr and that M 54 has spiraled into the potential well of the nucleus. If this scenario (which needs further investigations) is correct, galactic nuclei were finally demonstrated to be a distinct class of object with respect to Globular Clusters.

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