BLUE STRAGGLERS IN GALACTIC GLOBULAR CLUSTERS: PLAYING WITH SPECIFIC QUANTITIES

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ABSTRACT

We present preliminary results obtained from the comparison of the specific frequencies of Blue Straggler Stars (BSS) detected so far in a sample of 26 Galactic globular clusters.

The number of BSS seems to increase almost linearly with increasing the amount of sampled light in loose clusters, while it drops abruptly for clusters having intermediate-high central densities. In particular, a simple interpretative scenario where the BSS in loose clusters are produced from primordial binaries and those detected in high density globulars are due to star interactions leading to binary formation, merging, etc. seems compatible with these early results.

The possibility that this observational evidence could be ascribed to systematic biases mostly related to the increasing difficulty to detect BSS candidates with increasing cluster concentration, is also discussed.

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1. INTRODUCTION

Many new results are now supporting the claim that dynamical evolution of globular clusters (GCs) can affect the evolution of their stellar populations. In fact, both the integrated cluster colors (Djorgovski et al. 1988, Piotto et al. 1988, Bailyn et al. 1989, 1992, Aurière et al. 1990, Stetson 1991, Cederbloom et al. 1992, etc.) and the properties of special individual stars (Horizontal Branch (HB): Buonanno et al. 1985, 1986, 1991, Ferraro et al. 1992a, Fusi Pecci et al. 1993a, Blue Stragglers (BSS): Fusi Pecci et al. 1992, Sarajedini 1992, Ferraro et al. 1993), confirm the existence of dynamically induced variations in the evolution of many cluster members.

Moreover, as recently reviewed by Bailyn (1993), there is now a variety of observational results which are direct or indirect evidences of the existence and impact of various kinds of binary systems in globular clusters. Physical interactions between stars are quite probable, and significant modifications of the populations of both single and binary stars can naturally be expected.

As a consequence, it seems natural to conclude that a combination of several phenomena somehow related to binaries and/or environment may be responsible for the stellar
population gradients, for the properties of the BSS and HB stars, for the existence of rare or even “exotic” objects, for the production of millisecond pulsars and X-ray sources, etc.

In particular, as widely reviewed by many authors in several recent papers (Nemec 1989, 1991, Leonard 1989, Fusi Pecci et al. 1992, Bailyn 1992, Stryker 1993 and references therein), there is a growing belief that binaries via various mechanisms (e.g. coalescence, merging, interaction, capture) can be related to the origin of the BSS detected in Galactic GCs.

The recent growing body of observations reporting new detection of BSS candidates in Galactic GCs from the ground (see Fusi Pecci et al. 1992, 1993b for references) and with HST just at the center of highly concentrated globulars (Aurière et al. 1990, Paresce et al. 1991, De Marchi et al. 1993, Ferraro and Paresce 1993, Lauzeral et al. 1993, Bailyn and Mader 1993) has renewed the interest of the astronomical community on this topic, strongly emphasizing the need for appropriate inter-cluster comparisons in order to detect any possible correlation between the cluster overall parameters and the observed BSS properties.

In this respect, we have already presented (Fusi Pecci et al. 1992, Ferraro et al. 1993) some observational evidences supporting the existence of possible correlations between cluster structural parameters and BSS properties. In particular, we found that:

(i) The BSS Luminosity Function (LF) for low density GCs ($Log\rho_0 < 3$) turns out to be different from that obtained for the BSS detected so far in highly concentrated GCs ($Log\rho_0 > 3$), at 3$\sigma$ level.

(ii) There are some (weak) indications that the ridge line of the BSS sequence in the CMD is progressively red-shifted compared to the bright extension of the Zero Age Main Sequence with increasing metallicity.

(iii) In M3, the BSS radial distribution normalized to the sampled light presents a strongly different behaviour with respect to that of “normal” stars in the same magnitude range, and there is a lack of BSS in an intermediate annular region of the cluster which could be ascribed to the existence of two different populations of BSS within the same cluster or to segregating effects in the BSS production and/or survival (Ferraro et al. 1993).
In this paper, we report on the first quantitative comparison of the rate of production/survival of BSS in the Galactic GCs where such objects have actually been detected so far. Since it is highly probable that the available sample of BSS (625 listed in Table 2 of Fusi Pecci et al. 1993b) is still substantially incomplete, especially for the dense clusters, important caveats on the use of BSS specific quantities are also discussed.

2. THE DATA SET

Table 1 presents the list of 26 GCs containing BSS for which \( r_c \) – the core radius – and \( r_t \) – the tidal radius – are known, and precise information on the area covered by the observations could be found. The selection of the BSS have been made by visual inspection of the published Color Magnitude Diagrams, whose reference has been reported in column 9 (see also Fusi Pecci et al. 1992). In particular, for each GC we list:

1. The cluster name.
2. The logarithm of the central mass density \((\log \rho_0)\) in \( M_\odot pc^{-3} \) from Webbink (1985).
3. The concentration parameter \((c = \log r_t/r_c)\). To keep homogeneity in the data-source, this value has been computed starting from the observed values of \( r_t \) and \( r_c \) listed in the Webbink compilation. Note that the use of any other list of similar data would leave the present results and discussion substantially unchanged.
4. The absolute magnitude \((M_V)\) computed scaling the apparent integrated magnitudes listed by Webbink (1985) for the appropriate GC distance modulus (see below). Small differences between the values listed here and those adopted in our previous papers (Fusi Pecci et al. 1992, 1993b) are actually irrelevant for the present purposes.
5. The metal abundance \(([Fe/H])\) taken from Zinn (1985).
6. The bolometric luminosity of the surveyed area in unity of \(10^4 L_\odot\) (hereafter \( L_S \)) defined below.
7. The number of the adopted BSS \((N_{BSS})\) selected on photometric grounds (see Fusi Pecci et al. 1992).
8. The specific frequency \( S4_{BSS}\), see Sect. 3.
9. The crowding parameter \( F\), defined and discussed in Sect. 3.2 to estimate somehow the possible influence of crowding effects.
The bolometric luminosities of the surveyed areas ($L_{Bol} = 1.4L_V$, Buzzoni 1985 private communication) have been computed by numerical or analytical integration of a King model (King, 1966) described by the three observed parameters $r_c, r_t, \sigma$ – i.e. core radius, tidal radius and central brightness (from Webbink 1985), and imposing the boundary condition that the integral of the model brightness profile between 0 and $r_t$ must be equal to the total cluster luminosity $M_V$.

The adopted distances have been obtained by calibrating the observed luminosity level of the HB, $V_{HB}$ (taken from Armandroff, 1989) with the relation proposed by Lee et al. (1990) $M^H_{V}\ = \ 0.17[Fe/H] + 0.82$, and adopting the reddening listed by Zinn (1985).

**Important caveat:** As already emphasized by Fusi Pecci et al. (1992), the available GC sample is very incomplete and heterogeneous in the photometric sampling actually achieved by the individual photometries carried out by the various authors.

For instance, some clusters (mostly the loose ones) have been properly surveyed down to the Main Sequence Turnoff (or even fainter) almost uniformly. In many objects the survey has been limited to the more external areas, and, on the contrary, in a few others the very inner regions have been observed with HST at a much higher resolution.

This sampling bias is very insidious and must be always recalled while discussing any result on this subject. In particular, since strong variations in radial distributions of BSS with respect to “normal” stars of similar magnitude have already been repeatedly pointed out, any comparison of BSS number as a function of the distance from the cluster center must be done with special care, and also the comparisons based on total numbers of detected BSS could be strongly in error.

On the other hand, though still in its early childhood, the attempt of looking for possible correlations of BSS with cluster properties may be of tremendous importance to understand better the BSS and the whole subject involving globular cluster population and environment. Therefore, we present below and discuss the results one can derive with the available data as a first step in a long path which will be hopefully checked soon and corroborated by further data. Consequently, the use of the figures listed in the tables
must be done with particular care and being aware of the possible bias still affecting them.

3. RESULTS AND DISCUSSION

3.1. Playing with BSS absolute numbers

In Figure 1, the number of the detected BSS \( N_{BSS} \) – has been plotted as a function of the sampled light \( L_S \), expressed in unit of \( 10^4 L_\odot \) (panel a), and versus the fraction of the total cluster light actually sampled (panel b).

As can be seen from the plots, at a first inspection it is hard to find any overall meaningful correlation and one could simply conclude that the data are still too uncertain and scattered to draw any indication.

However, for a deeper analysis, it may be useful to divide the cluster set into two sub-groups, based on the values of \( L_S \) – the cluster light actually sampled in the considered observations. So doing, one could get some interesting hints.

(i) \( L_S < 6 \times 10^4 L_\odot \)

Among the 18 GCs present in this sub-group, \( N_{BSS} \) seems to increase with \( L_S \) according to the relation: \( N_{BSS} = 6.57 \times L_S + 10.1 \), with a linear correlation coefficient \( r = 0.76 \), (yielding a probability of \( \sim 99.99\% \) that the two quantities are actually correlated each other).

(ii) \( L_S > 6 \times 10^4 L_\odot \)

This sub-group includes only 8 objects and its statistical significance is therefore quite low. However, not only there is no evidence for the existence of any trend similar to that found in the previous sub-group, but it seems remarkable to note that all the clusters are far from being located on the extension of the previous relation and display a much lower number of BSS than expected if a similar incidence per fixed sampled light is adopted.

An obvious explanation for this result could be the existence of a bias in the BSS search which would lead to an increasing incompleteness with increasing the sampled light. This may well be occurred, but \textit{a priori} there is no obvious reason to explain why BSS should be lost at a larger extent while increasing the light sampling.
Alternatively, one could imagine three possible explanations: (i) the light sampled in these clusters is not “truly-representative” of the average cluster population; (ii) the light sampled in the cluster is “truly-representative” of the average cluster population, but the BSS are peculiarly distributed and the light actually sampled is BSS-poorer than the non-sampled fraction; (iii) the clusters included in the two considered sub-groups are “intrinsically” different as far as BSS production/survival is concerned.

To explore item (i), we refer to Fig. 1b. As can be seen, the 8 clusters included in the second sub-group (full dots) display a distribution of fractional sampled light (i.e. $L_S/L_{tot}$) similar to those membering the first sub-group (open dots). In particular, there are 4 objects (over 8) sampled at more than 50% and only 2 at less than 20%. Hence, though possible, alternative (i) seems to be improbable.

Concerning item (ii), the discussion is much more complicated. In fact, different regions of the clusters have in general been surveyed with different instrumental setups. Therefore, if BSS have a peculiar distribution with respect to “normal” stars, one could well even lose a whole huge BSS population if the “wrong” areas are sampled.

Is this the case for the 8 considered clusters? Maybe, but it is not sure, and the answer may differ from cluster to cluster. For instance, 47 Tuc and M15 have been observed with HST in the central regions and repeatedly observed from the ground in the outer parts. A small group of undetected BSS may well be present, but the existence of a very large undetected BSS population seems beyond the predictions one could imagine on the present grounds. On the other hand, for example NGC 2419 is a very far and rich cluster, and the MS Turnoff has been barely observed so far. There is thus no reason to exclude that very many BSS could have been overlooked. It would thus be curious that “wrong” areas or insufficient search quality have been adopted while sampling more and more cluster light, but it cannot be excluded at this stage.

If we assume for sake of reasoning that alternative (i) and (ii) could be overcome, it may be eventually useful to verify whether there is at least one parameter significantly different between the two sub-groups, which could somehow originate an “intrinsical” difference between the clusters as far as the BSS are concerned.

The most evident difference between the two sub-groups is the cluster concentration. In fact, the mean central density is $< Log\rho_0 = 1.5 \pm 0.3 >$ and $< Log\rho_0 = 3.3 \pm 0.5 >$, respectively.
Hence, though the difference is not very strong on statistical grounds, one could have that while in loose clusters the number of the detected BSS is proportional to the sampled light, in the intermediate-high density globulars $N_{BSS}$ drops with respect to this relation, and the actual number of BSS depends on various other factors (to be found). The present data would indicate in particular a low number of BSS in high density clusters even if a large fraction of the total light is sampled in the central regions.

Since it is now widely accepted (see Stryker 1993 for a review) that BSS may originate through several processes, it is also quite evident that, if BSS of different origin populate different clusters (or even different regions of the same cluster, Fusi Pecci et al. 1992, Ferraro et al. 1993), it may be natural to expect the existence of (various) different relationships between the overall cluster properties and the BSS frequency.

On the other hand, it is also immediate to note that, independent of any peculiarity in the BSS radial distribution, the BSS detection is more difficult and less “safe” when dealing with more and more concentrated clusters. And thus, by explaining the detected effect as due to cluster concentration, one could indirectly fall back to the selection bias.

In summary, there are serious indications that the available samples of BSS is still inadequate to allow any firm conclusions. However, the emerging indications, if confirmed, could also be compatible with an interpretative scenario where in loose clusters the BSS form from primordial binaries and their number is roughly proportional to the sampled luminosity. With increasing the cluster concentration and the number of cluster members, primordial binaries become less and less efficient as BSS progenitors while collisional binaries take place, and the BSS number actually depends on a variety of parameters related to the type of star interactions and mechanism originating the BSS themselves.

As a consequence, it may be worth of the effort, on the one hand, the extension of this analysis to make more direct the comparisons among different clusters, and on the other, a deeper discussion of the possible influence of crowding effects on the whole photometric treatment. To this aim, relative and normalized quantities are much better than absolute numbers. Therefore, we define and use below a new quantity to make more evident the bulk of the present result. Then, we deal with crowding impact.

3.2. Playing with BSS normalized quantities

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Bolte et al. (1993) defined the BSS specific frequency $F_{\text{BSS}}$ as the number of BSS with respect to the number of all the observed stars brighter than two magnitudes below the Horizontal Branch level. Though very useful in principle, this relative quantity can hardly be precisely computed at this time in the GCs where BSS have been detected so far since most of the photometric surveys are not sufficiently reliable in this respect. In fact, quite often bright stars in the observed fields are saturated due to the long exposure needed to reach the TO region with an appropriate S/N ratio and the completeness checks for both bright and faint stars are insufficient or inexistent at all.

For these reasons we defined (Ferraro et al. 1993) a different BSS specific frequency in terms of the sampled luminosity as $S_{4BSS} = N_{BSS}/L_S$ where $N_{BSS}$ is the number of the detected BSS and $L_S$ is the integrated bolometric luminosity of the surveyed area in unity of $10^4 L_\odot$.

Admittedly, if available, the specific frequency defined by Bolte et al. is better as it is based on “true” numbers and not on integrated properties. However, our quantity has the advantage of being measurable directly on the used frames (by properly calibrating the integrated flux collected by the receiver) or, in absence of the necessary observational data, it can also be (roughly) computed by knowing the cluster brightness profile and the exact location and size of the surveyed area.

In Figure 2 we present the distribution of the $S_{4BSS}$—values obtained for the 26 GCs listed in our catalog. In summary:

a) The specific frequency (as computed with the available samples) can vary from cluster to cluster by a factor $\sim 30$.

b) The quite strong incidence of clusters with small specific frequencies runs parallel to the effects due to detection losses and selection bias. It seems quite improbable that the observed large variation can be totally ascribed to just systematic effects, but frankly it cannot be firmly excluded at this stage.

c) Taken at face value, the $S_{4BSS}$ weighted mean turns to be $< S_{4BSS} > = 10 \pm 2$, where the weights have been computed taking into account only the Poisson error in the star counts, (i.e. assuming the uncertainty in the sampled light to be trascurable). The mean standard deviation ($\sigma$) is quite high ($\sigma \sim 8$), and the observed distribution is
still compatible with a Gaussian distribution. Under this assumption, the probability of finding 8 objects in the beam $0 < L_S < 4$ (see Figure 2) is only 0.7%. Of course, this may also be taken as another indication that a bias is surely present in the available sample.

Assuming that the $S4_{BSS}$ values are sufficiently reliable, it is useful to plot them versus some intrinsic structural parameters of the BSS parent cluster.

In Figure 3a,b,c the specific frequency $S4_{BSS}$ of each cluster has been plotted versus the integrated cluster magnitude $M_V$, the central density $Log\rho_0$, and the concentration parameter $c$, respectively. As can be seen, in the diagrams there are always two well separated regions: a permitted zone, sparcely populated, and a sort of forbidden zone completely empty. Note that an arbitrary dash line has been reported in the plots in order to put into better evidence the effect.

The interpretation of these plots may be risky at this stage, but also interesting to note for future studies. In synthesis, one could see a quite clear indication that there is a lack of clusters having high density and/or large number of stars (bright $M_V$) and large BSS specific frequency, while with decreasing total luminosity and/or concentration, clusters display a quite wide set of possible $S4_{BSS}$ values.

How confident can one be that the observed effect has something to do with reality and is not just the perverse combination of various factors, even in presence of non-misleading data?

The problem is quite tricky since:

i) As shown for example in the catalog compiled by Djorgovski and Meylan (1993), concentration and central density are well correlated with integrated luminosity (see their Figure 2) in the sense that luminous clusters generally have smaller cores and higher concentration. Hence, all quantities depending on integrated luminosity turn to be automatically correlated also with the structural parameters of the clusters.

(ii) The absolute luminosity actually sampled in the considered clusters is strongly correlated ($r=0.81$) with the total integrated luminosity of each cluster (see Figure 4) as one cannot sample more light than available in low luminosity clusters.
iii) $S_{4BSS}$ is by definition strongly dependent on the sampled luminosity and, in turn, via points (i)-(ii) on the structural parameters. On the other hand, it is important to stress that any specific frequency (including the one adopted by Bolte et al., based on star counts, see below) has this implicit dependence when plotted versus the cluster structural parameters.

To explore a bit further the issue, we report in Figure 5a $S_{4BSS}$ versus $M_V$ to be compared with the data in Figure 5b, where the quantity $1/L_s$ referred to each cluster is plotted versus the same abscissa.

It is quite evident that the observed number of BSS introduces only a sort of second order perturbation to the trend driven by $L_S$. Moreover, this depends only marginally from the sampling level of the cluster. In fact, assuming for sake of simplicity the best observative hypothesis (i.e. the total cluster light $L_T$ actually sampled), one gets the solid line in Figure 5b (i.e. $1/L_T$, vs $M_V$). In other words, since low density clusters are in general intrinsically poor, $S_{4BSS}$ grows up easily for them even with a few detected BSS. On the contrary, only a huge number of BSS detections could move a cluster like 47 Tuc (highly concentrated and rich) from its position in this diagram.

On the other hand, since at present the number of BSS actually detected in 47 Tuc is small (though the cluster has been widely observed both from the ground and with HST), the relative paucity of BSS in 47 Tuc with respect to the typical loose clusters seems to be noteworthy.

The use of star counts to compute the specific frequency as done by Bolte et al. (1993) leads similarly to a quantity which is implicitly related to the cluster luminosity and stellar density as the numbers of giant branch and horizontal branch stars detectable in a given region of the cluster are proportional to the cluster sampled light (see the so-called “Fuel Consumption Theorem”, Renzini and Buzzoni 1986).

To directly verify this and to compare the specific frequency we defined with the one adopted by Bolte et al. 1993, we have computed and listed in Table 2 the specific frequencies computed for 5 clusters where all the needed quantities are available to us in a computer readable form. In addition, we have also listed in column 4 the number of HB plus RGB stars (brighter than the HB level) observed and those predicted by inserting our estimated sampled luminosity in the relation (Renzini and Buzzoni, 1986):

$$N_j = B(t)L_{stj}$$
where $L_S$ is the sampled luminosity (see column 6 of Table 1), $t_j$ is the duration of the considered phase, and $B(t)$ is the evolutive flux. In the computations we have assumed from Renzini and Buzzoni (1986) and Buzzoni et al. (1983) $B(t) = 2 \times 10^{-11}$, $t_{HB} = 10^8$ yr, and $t_{RGB} = 7.3 \times 10^7$ yr (corresponding to the RGB lifetime spent above the HB level).

As can be seen from the Table 2, the numbers of predicted and observed stars are in excellent agreement, confirming that our adopted procedure to estimate $L_S$ is reliable enough to avoid any bias. Moreover, the plot presented in Figure 6, reporting our specific frequency $- S_{4BSS}$ versus the similar quantity determined by using the definition of Bolte et al. (1993), shows that the two observables are strictly correlated, as expected. Hence, the use of the BSS specific frequencies to study the possible existence of clear-cut correlations between them and the parent cluster overall properties is really informative only if they are related to parameters which are fully independent of the cluster absolute magnitude.

3.3. Crowding effects: further caveats

Since it is immediate to imagine that the available data must be influenced by crowding, it is useful to add some information and a greater discussion of its possible effects on our procedure.

In the search for BSS candidates there are at least three basic aspects which may introduce significant biases in the samples:

1. The quality of the seeing or, more in general, the actual spatial resolving power during the observations.

2. The magnitude limit actually reached in the photometry, i.e. how faint and precise are the measures down to the cluster turnoff.

3. The intrinsic crowding in the cluster sampled region, which is function of the cluster structural parameters and, for given observational setup, of the cluster distance.

Concerning the seeing, it is quite obvious that it is really discriminant only when the properties mentioned in items 2 and 3 are the same. We collected the very poor information on the seeing conditions of the CMD’s used in Table 1 and found that they range from 0.5
up to 2 arcseconds. Curiously enough, a plot of the quoted seeing (usually the FWHM of the average star of the average frame) versus the number of detected BSS displays an anti-correlation (many BSS detected in clusters observed in bad seeing conditions!). This result shows that the detection of BSS candidates has been so far only marginally dependent on the actual seeing conditions (probably because intermediate-quality nights have been generally used to study loose clusters), and suggest that the most important factors have actually been the deepness and the degree of completeness achieved in the photometric surveys.

In this respect, it may be interesting to recall the case of the cluster IC 4499. In a forthcoming study (Ferraro et al. 1994), we observed the same cluster region as observed by Sarajedini (1993), in very similar seeing conditions but we reached about two magnitudes fainter and found almost twice as many BSS candidates as Sarajedini.

To study further the possible impact of crowding, we have computed the crowding parameter $F$ defined as:

$$F = A_{s_i}/A_{frame}$$

with $A_{s_i} = 80 \times L_S \times \pi \times FWHM^2$ (arcsec$^2$), $A_{frame}$ = observed area in arcsec$^2$, and where 80 is the conversion coefficient (star/luminosity) computed via the quoted Fuel-Consumption Theorem (Renzini and Buzzoni 1986), $L_S$ is the sampled luminosity as determined above, and $FWHM$ is the adopted figure for the seeing conditions in the adopted cluster photometry.

In synthesis, since $F$ yields an estimate of the fraction of the frame actually covered by stars, it should roughly rank the clusters listed in our sample according to both intrinsic crowding and seeing impact.

Figure 7 reports the distributions of the absolute ($N_{BSS}$) and specific ($S4_{BSS}$) numbers of BSS candidates with varying the corresponding available $F$ values.

At first sight, inspection of the plots leads to two main conclusions:

a) The number of BSS candidates actually detected so far in the clusters is sufficiently uncorrelated to $F$ i.e. $N_{BSS}$ do not show any clear-cut trend with varying $F$. 

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b) The specific frequency $S_{4\text{BSS}}$ seems to be correlated to $F$, in the sense that the specific frequencies increase with improving the crowding conditions. This evidence could reinforce the idea that $S_{4\text{BSS}}$ is the critical parameter to determine since we expect that the results of the BSS search must be influenced by crowding and seeing. On the other hand, we cannot conclude based on this plot that there is surely a bias induced by crowding in the available data because of the quoted implicit dependence on $L_S$ of both $S_{4\text{BSS}}$ and $F$.

In fact, $F \propto L_S$ and $S_{4\text{BSS}} \propto 1/L_S$. Hence, if $L_S \to 0$ just a few BSS automatically lead towards “high” $S_{4\text{BSS}}$ values, with very small figures for $F$.

4. CONCLUSIONS AND FUTURE PROSPECTS

Using the available data on BSS in Galactic GCs and being fully aware of the possible existence of important incompleteness and bias in the adopted sample, we have here started a comparison between the various parent clusters based on absolute BSS numbers and corresponding normalized quantities.

The number of BSS detected so far seems to increase almost linearly with increasing the amount of sampled light in loose clusters, while the trend changes abruptly for clusters having intermediate-high central densities. In particular, highly concentrated objects have much less BSS detected so far per unit luminosity than loose globulars. However, this evidence could also be ascribed to the increasing difficulty to detect BSS candidates with increasing cluster concentration.

If confirmed by further data, this observational result is very important to understand better the BSS origin and the whole complicate interplay taking place within each cluster between binary formation, evolution, and survival and the comprehensive dynamical evolution of the global cluster environment.

In particular, an interpretative framework which explains the BSS in loose clusters as produced from primordial binaries and those detected in high density globulars as due to star interactions leading to binary formation, merging, etc. seems compatible with these early results.
A systematic search for BSS, spanning from the very central regions of the clusters to their outskirts, is a crucial prerequisite to make a significant breakthrough on this interesting issue.

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References

Anthony-Twarog, B.J., Twarog, B.A., 1992, AJ 103, 1264.
Armandroff, T.E., 1989, AJ, 97, 375.
Aurière, M., Ortolani, S., and Lauzeral, C., 1990, Nature, 344, 638.
Bailyn, C.D., 1993, in Dynamics of Globular Clusters, eds S. Djorgovski and G. Meylan, ASP Conference series 50, p. 191,
Bailyn, C.D., Grindlay, J.E., Cohn, H.N., Lugger, P.M., Stetson, P., Hesser, J.E., 1989, AJ 98, 882.
Bailyn, C.D., Sarajedini, A., Cohn, H., Lugger, P.M., Grindlay, J.E., 1992, AJ, 103, 1564.
Bailyn, C.D., Mader, V., 1993, in “Blue Stragglers”, ed. M. Livio and R. Saffer, ASP conf.
   Series 53, p. 177.
Bolte, M, 1992, ApJS 82, 145.
Bolte, M, Hesser, J.E., Stetson, P.B., 1993, ApJ 408, L89.
Brewer, J.P., Fahlmann, G.G., Richer, H.B., Searle, L., Thompson, I., 1993, AJ 105, 2158.
Buonanno, R., Corsi, C.E., Fusi Pecci, F., 1985, A&A 145, 97.
Buonanno, R., Caloi, V., Castellani, V., Corsi, C.E., Fusi Pecci, F. and Gratton, R.G. 1986, A&AS 66, 79.
Buonanno, R., Buscema, G., Fusi Pecci, F., Richer, H.B., and Fahlman, G.G., 1990, AJ 100, 1811.
Buonanno, R., Fusi Pecci, F., Cappellaro, E., Ortolani, S., Ritchler, R.T., Geyer, H.E. 1991, AJ, 102, 1005.
Buonanno, R., Corsi, C.E., Buzzoni, A., Cacciari C., Ferraro, F.R. Fusi Pecci, F., 1994, A&A (in press).
Buzzoni, A., Fusi Pecci, F., Buonanno, R., Corsi, C., 1983, A&A 123, 94.
Carney, B.W., Kellar Fullton, L., Trammell, S.R., 1991, AJ 101, 1699.
Cederbloom, S., Moss, M., Cohn, H., Lugger, P., Bailyn, C., Grindlay, J., McClure, R. 1992, AJ, 103, 480.
Christian, C.A., and Heasley, J.N., 1986, AJ 303, 216.
Christian, C.A., and Heasley, J.N., 1988, AJ 95, 1422.
Christian, C.A., Heasley, J.N., 1991, AJ 101, 967.
Coté, P., Richer, H.B., and Fahlman, G.G., 1991, ApJ 102, 1358.
De Marchi, G., Paresce, F., Ferraro, F.R., 1993, ApJS 85, 293.
Djorgovski, S.G., Piotto, G., King I.R., 1988, in Dynamics of Dense Stellar System, ed. D. Merritt, (Cambridge Univ. Press), p. 147.
Djorgovski, S.G., Meylan, G., 1993, (preprint).
Ferraro, F.R., Clementini, G., Fusi Pecci, F., Buonanno, R., 1991, MNRAS 252, 357.
Ferraro, F.R., Clementini, G., Fusi Pecci, F., Sortino, R., and Buonanno, R. 1992a, MNRAS, 256, 391.
Ferraro, F.R., Fusi Pecci, F. Buonanno, R., 1992b, MNRAS 256, 376.
Ferraro, F.R., Paresce, F., 1993, AJ, 106, 154.
Ferraro, F.R., Fusi Pecci, F., Cacciari, C., Corsi, C.E., Buonanno, R., Fahlman, G.G., Richer, H.B., 1993, AJ 106, 2324.
Ferraro, F.R., et al, 1994. (to be submitted).
Fusi Pecci, F., Ferraro, F.R., Corsi, C.E., Cacciari, C., and Buonanno, R. 1992, AJ, 104, 1831.
Fusi Pecci, F., Ferraro, F.R., Bellazzini, M. Djorgovski, S.G., Piotto, G., and Buonanno, R. 1993a, AJ, 105, 1145.
Fusi Pecci, F., Ferraro, F.R., Cacciari, C., 1993b, in “Blue Stragglers”, ed. M. Livio and R. Saffer, ASP conf. Series 53, p. 97.
Gratton, R.G., and Ortolani, S., 1984, A&ASS 57, 177.
Guhathakurta, P., Yanny, B., Schneider, D.P., Bahcall, J.N., 1992, AJ 104, 1790.
Harris, H.C., 1993, AJ 106, 604.
Hodder, P.J.C., Nemec, J.M., Richer, H.B. Fahlman, G.G., 1992, AJ 103, 460.
Holland, S., and Harris, W.E., J.N., 1992, AJ 103, 131
Kaluzny, J., Krzemiski, W., 1993, Acta Astronomica, in press.
King, I. R. 1966, AJ, 71, 64
Lauzeral, C., Ortolani, S., Aurière, M., Melnick, J.1993, A&A 262, 63.
Lee, Y.W., Demarque, P., Zinn, R., 1990, AJ 350, 155.
Leonard, P.J.T., 1989, AJ 98, 217.
Nemec, J.M., 1989, In “The use of Pulsating Stars in Fundamental Problems in Astronomy”, IAU Colloquium No. 111, eds. E.J. Schmidt (Cambridge University Press), p. 215.

Nemec, J.M. 1991, Nature, 352, 286

Nemec, J.M., and Cohen, J.G., 1989, ApJ 336, 780.

Nemec, J.M., and Harris, H.C., 1987, AJ 316, 172.

Piotto, G., King I.R., Djorgovski, S.G., 1988, AJ, 96, 1918

Paresce, F., Shara, M., Meylan, G., Baxter, D., Greenfield, P., Jedrzejewski, R., Nota, A., Sparks, W.B., Albrecht, R., Barbieri, C., Blades, J.C., Boksenberg, A., Crane, P., Deharveng, J.M., Disney, M.J., Jakobsen, P., Kamperman, T.M., King, I.R., Macchetto, F., Mackay, C.D., and Weigelt, G. 1991, Nature, 352, 297

Renzini, A., Buzzoni, A., 1986, In Spectral Evolution of Galaxies, eds. C. Chiosi, A. Renzini, (Dordrecht: Reidel), p.135.

Sandage, A. 1953. AJ 58, 61.

Sarajedini, A., and Da Costa, G.S., 1991, AJ 102, 628.

Sarajedini, A., 1993, AJ 105, 2172.

Seitzer, P., Carney, B.W., 1990, AJ 99, 229.

Smith, G.H., McClure, R.D., Stetson, P.B., and Hesser, J.E., 1986, AJ 91, 842.

Stetson, P.B., VandenBerg, D.A., Bolte, M., Hesser, J.E., Smith, G.H., 1989, AJ 97, 1360.

Stetson, P.B., 1991, In Precision Photometry, eds. A.G.D. Philip, A. Upgren and K.A. Janes (Davis, Schenectady), p. 69.

Stryker, L.L., 1993, PASP, in press.

Webbink, R.F., 1985, *Dynamics of Star Clusters*: ed. J. Goodman and P. Hut (Dordrecht: Reidel), p. 541.

Zinn, R.J., 1985, ApJ 293, 424.
Figure Captions:

**Figure 1.** The observed number of Blue Straggler Stars ($N_{BSS}$) as a function of the sampled light ($L_S$): expressed in unity of $10^4 L_\odot$ (*panel a*) and as percentage of the total cluster light (*panel b*). The position of two clusters (NGC 5272 and NGC 2419) are indicated by arrows since their coordinates are outside the axis range. The vertical dashed line in *panel (a)* divides the two sub-samples showing different behaviour with increasing $L_S$ (see text). The *full dots* in *panel (b)* mark clusters with $L_S > 6 \times 10^4 L_\odot$.

**Figure 2:** Histogram of the distribution of $S4_{BSS}$ in the Galactic GCs listed in our catalog.

**Figure 3:** $S4_{BSS}$ vs cluster structural parameters: *panel (a)* the integrated absolute magnitude, $M_V$; *panel (b)* the logarithm of the central stellar density, $Log\rho_0$; *panel (c)* the concentration parameter $c$. The *dashed line* has been arbitrarily traced to put into evidence the effect discussed in the text.

**Figure 4.** Plot of the cluster total light ($L_T$) versus the sampled light, $L_S$. Note the tight correlation ($r=0.81$) existing between the two quantities. The object indicated by an arrow is NGC 5272 (whose actual coordinates: 40,50).

**Figure 5:** The bias affecting different BSS specific quantities as function of the absolute magnitude $M_V$:

*panel (a)* - The $S4_{BSS}$ parameter.

*panel (b)* - The inverse of the sampled light ($1/L_S$). As can be seen, the trend showed in *panel (a)* is partially due to the relationship necessarily linking $L_S$ and $M_V$. The *solid line* represent the inverse of the total cluster light.

**Figure 6:** Comparison between the BSS specific frequency defined in this paper ($S4_{BSS}$) and $F_{BSS}$ (Bolte *et al.* 1993).

**Figure 7:** The crowding parameter $F$ opposed to $N_{BSS}$ (*lower panel*) and to $S4_{BSS}$ (*upper panel*). Note that $F$ increase as the crowding condition worsen (see text).