THE YOUNG GLOBULAR CLUSTERS OF THE MILKY WAY
AND THE LOCAL GROUP GALAXIES:
PLAYING WITH GREAT CIRCLES

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ABSTRACT

The small group of Galactic Globular Clusters (GGC) (Pal 12, Terzan 7, Ruprecht 106, Arp 2) recently discovered to be significantly younger (by $\sim 3 - 4$ Gyr) than the average cluster population of the Galaxy are shown to lie near planes passing in the vicinity of some satellite galaxies of the Milky Way and through the Galactic Centre itself.

Assuming that these configurations represent a fossil record of interactions between the Galaxy and its companions from which these clusters originated, we identified, along one of them, another candidate “young” GGC, *i.e.* IC4499, whose Color-Magnitude Diagram is presented.

Various hypotheses on the possible origin of “young” GGC are also briefly discussed within a framework where the location on preferential planes may be seen as a general characteristic for the Local Group members.
1. INTRODUCTION

The evidence that several satellites of the Milky Way appear to be situated along a few great circles (streams), and that this may be somehow related to their origin and dynamical and chemical evolution, has been a sort of unsettled but persistent theme in the last twenty years or so for most studies of the stellar systems (galaxies and clusters) populating the Local Group. In particular, Hodge and Michie (1969), Kunkel and Demers (1977), Kunkel (1979), Lynden-Bell (1976, 1982) and others (see the reviews by Majewski 1993a,b) pointed out the existence of two remarkable great circles which account for most of the dwarf satellites of the Milky Way. The first, the Magellanic Plane (MP, Kunkel and Demers 1977), at an angle of about 40° with respect to the plane defined by the Magellanic Stream (MS), roughly passes through the Magellanic Clouds, the Galactic Centre and the Draco-Ursa Minor region. The second, called by Lynden-Bell (1982) the Fornax - Leo - Sculptor Stream (FLS), ideally contains in a plane Fornax, Leo I and II, and Sculptor.

Concerning the Galactic globular clusters (GGCs), as recently reviewed and discussed for instance by Zinn (1993), van den Bergh (1993), and Majewski (1993b, 1994), there are now many indications suggesting the existence of different populations (e.g. disk, old and young halo, etc.) possibly originated via different mechanisms. Moreover, the possibility of an early history of the Galaxy affected by tidal interactions, mergers or captures, involving satellite galaxies and outer halo globular clusters has recently received a noticeable support by the latest discovery of the Sagittarius dwarf spheroidal galaxy (Sgr dSph) currently being disrupted and absorbed by the Milky Way (Ibata et al. 1994, Mateo et al. 1994).

Our specific interest in this subject originates from the early detections of a small (but growing) set of globular clusters which are significantly younger (by 3-4 Gyr) than the bulk of the cluster population studied so far in our own Galaxy, i.e. Pal 12 (Gratton and Ortolani 1988, Stetson et al. 1989), Ruprecht 106 (Buonanno et al. 1990, 1993), Arp 2 (Buonanno et al. 1994a,b), and Terzan 7 (Buonanno et al. 1994a,c). As stressed in a previous paper (Buonanno et al. 1994a), we noted that these four clusters appear to lie nearly along a great circle in the sky and, following an early suggestion by Lin and Richer (1992), we were led to conclude that they could be on similar orbits and may have been captured by the Milky Way. Our present analysis of the available data on locations and kinematics of the known stellar systems in the Local Group is strongly centered on the problem of the origin of the young globulars of the Galaxy and has two aims:

(1) Search for additional candidate young Galactic globular clusters among those which are suitably located with respect to the most attractive configurations identified between the four known young globulars and the satellite galaxies.
(2) Analyze the configurations somehow linking young GGCs to the other satellites of the Milky Way to see if and how they could fit into the picture of a few great circles (planes) representing the signature of recent or old connections.

This is only a first step towards a comprehensive study of the dynamics, kinematics and chemical enrichment history of these stellar components, which will require more data (in particular proper motions and detailed chemical abundances) before it can produce conclusive results. However we believe it is worth reporting some preliminary results and speculations as a possible guide for further observations and models, especially since these have led us to pick up, maybe fortuitously, another “young candidate” (i.e. IC 4499, Ferraro et al. 1994), which confirms the potentiality of such a procedure.

2. DATA-SET AND PROCEDURE

Our database consists of all the Local Group galaxies, and the GGCs more distant than 10 Kpc from the Galactic Centre. The main reason for this choice is that since the Galactic Centre is the pivot of any plane, the objects too close to that point do not provide any significant information to distinguish between different solutions. The basic data-sources for the GGCs are from Thomas (1989, coordinates and radial velocities), Djorgovski (1993, metallicities), Armandroff (1989) and Peterson (1993) for $V_{HB}$ and $E(B-V)$. If missing from these sources, radial velocities and metallicities have been taken from other lists (Zinn 1985, Webbink 1985, Armandroff and Da Costa 1991, Freeman et al. 1983). The heliocentric and galactocentric distances have been calculated with the same assumptions as Armandroff (1989). The data on Local Group galaxies are drawn from van den Bergh (1994a) and Zaritsky (1994). It is important to stress that the use of any other reference source for these parameters would make substantially no difference since we are just looking at overall configurations hardly affected by the uncertainties associated to these observables. Conversely, it is important to note that the adopted distance scale is strictly homogeneous, so the description of the GGC system is fully self-consistent as far as standard candles and zero-points are concerned.

To carry out our tests we have selected various groups of interesting objects (for instance LMC, SMC, all dSph's, Arp 2, Terzan 7, Ruprecht 106, Pal 12 and many other objects in some way connected to them in previous studies) and have interactively checked their locations with respect to planes passing through any pair of them and the Galactic Center. When an interesting configuration was found we simply checked the characteristics of the possible members and then optimized the matching of the parameters involved in the description. The criteria that guide our judgement in recognising an “interesting” configuration are that a) the configuration is clearly defined, i.e. the distances of each object from the defined plane are as small as possible; and b) the maximum number of objects, in particular of young GGCs and Galaxy satellites, belong to the configuration. The position of the projection in the sky of the considered plane with respect to the Magellanic Stream was also considered. See Sect. 3.1 for more details.
The diagrams presented in Figure 1 and 2 are made adopting the approach of Lynden-Bell (1982, Table 1), i.e. we plot (a) the coordinates $l_G, b_G$ at which each object would be seen if viewed from the Galactic Centre, assumed to be at 8 Kpc from the sun and (b) the Galactic Great Circles which are the projection on the sky of the main planes discussed in text. The approximate location and extension of the Magellanic Stream has also been reported as derived from Kunkel (1979, Fig. 1).

3. RESULTS

Figure 1 shows a diagram where all the objects (clusters and galaxies) considered in the present analysis are plotted in the adopted reference frame ($l_G, b_G$) together with the Galactic Great Circles representing the quoted Magellanic Plane and Fornax-Leo-Sculptor Plane. If one considers that these planes are also passing through the Galactic Centre, some alignments are at least curious. For instance, the newly discovered Sgr dSph is not far from the Magellanic Plane in the sky, and the FLS-plane accounts fairly consistently for Sextans and even Phoenix (at about 400 Kpc indeed, see Majewski 1994). However, one has to recall that the Magellanic Clouds and the pair Draco-Ursa Minor lie nearly at the antipodes on the sky, and keeping these two nodes fixed it is possible to obtain a family of Magellanic Planes. This is why Kunkel and Demers (1977) and Lynden-Bell (1976) independently found similar planes accounting for the MCs and the pair Draco-Ursa Minor, yet tilted by an angle of more than 30°. On the other hand, though a causal connection implying a tight alignment of MCs, Galactic Centre, and the Draco-Ursa Minor pair is difficult to prove, it seems unlikely that several other satellites would fit these configurations just by chance.

Moreover, as pointed out by various authors (see Hernquist and Bolte 1993, and references therein) if some globular clusters formed or were captured during merger events or galaxy interactions, it seems natural that they would be found in tails, ribbon-like bridges and similar sub-structures which could retain their dynamical identity for more than one Gyr (Johnston and Hernquist 1993, Piatek and Pryor 1993, Johnston, Spergel and Hernquist 1995), that is for a time of the order of the estimated orbital period of the Sgr dSph (Velasquez and White 1995). Hence, one could in principle even detect various different planar distributions of remnants (though possibly deformed by later evolution) as a result of repeated close encounters or of the orbital decay of a satellite merging with a disk galaxy on a rather inclined orbit (see Quinn et al. 1993, Fig. 11).

3.1. How many Magellanic Planes?

Following the procedure described in Sect. 2, we found several Magellanic Planes which are compatible with many interesting objects. As stressed by Lynden-Bell (1982), any two points in the sky have a great circle passing through them, and one cannot pay too much attention to all curious alignments. However, we note that two of these great
circles, which are shown in Figure 2, are particularly interesting as they could also contribute to shed some light on the possible origin of the young globulars.

The first plane, that we have named MP-1, is reported in Figure 2 as a full line. In our view, the main characteristics that make this configuration worth of consideration are:

(1) It contains the MCs, Draco-Ursa Minor and the two young globulars Pal 12 and Ruprecht 106, which were found by Lin and Richer (1992) to have kinematical properties compatible with a capture from the MCs. Furthermore, van den Bergh (1994b) has argued for the association of Pal 12 specifically with SMC, on the basis of chemical and structural similarities.

(2) Its projection on the sky, i.e. the corresponding Great Circle, is nearly superposed to the Magellanic Stream.

To define a general criterium of membership of any object to a given plane we consider the angle formed by its radius vector to the Galactic Centre and the plane itself, and assume membership if the probability for this angle to be smaller than presently observed in a random distribution is less than 15%. The candidate members of MP-1 then are: SMC, UMi, Leo II, Ruprecht 106, Pal 12, IC4499, NGC 6101, NGC 6934, Pal 4, NGC 5053, NGC 5024 and NGC 5466, the only members farther than 2Kpc from the plane being Leo II and Pal 4.

The radial velocities of the MP-1 candidate members, corrected for the motion of the local standard of rest (LSR) assuming a Galactic rotation of $220Kms^{-1}$ and a solar motion of $20Kms^{-1}$ toward $l = 57^0, b = 22^0$ according to van den Bergh (1993), are plotted in Figure 3 against the orbital longitudes calculated on the plane. As can be seen, most of the candidate members are located on a sinusoidal curve, so showing kinematical compatibility with a Keplerian motion. The only evident exception is the highly retrograde cluster NGC 6934 which can thus be excluded from the group.

Besides the above properties, the clue which mainly supports our interest for this configuration is that another of its members, i.e. IC 4499, has been found by us to be a young globular cluster (see section 3.2).

On the other hand, three of the quoted members, i.e. NGC 5053, NGC 5024, and NGC 5466 are known to be very metal poor and old. Hence, any claim of having detected a “homogeneous group” is not defendible, or at least the degree of contamination by interlopers is quite large. In this respect it is however also important to note that, considering the available sample of about 20 clusters with reliable (relative) TO-ages (Buonanno et al. 1995), a $\chi^2$-test shows that the probability that three “young clusters” appear to belong just by chance to the same Great Circle in the sky is $\sim 11\%$, while such a probability for 3 “old” clusters is greater than $\sim 70\%$.

The Great Circle marked with a dashed line in Fig. 2 is the projection on the Galactic sky of another “curious” plane (hereafter MP-2), which is very similar to the Magellanic Plane presented in Fig. 1, but accounts nicely also for the positions of Sgr
dSph and of the two other young globulars detected so far, *i.e.* Terzan 7 and Arp 2. According to the criterium adopted above, the MP-2 candidate members are: SMC, LMC, Arp 2, Terzan 7, NGC 2298, NGC 2808, NGC 6229, NGC 6715, NGC 2419, UMi, Dra, Car, and Sgr dSph. None of them is farther than $7Kpc$ from MP-2. Moreover, three clusters (NGC 1466, NGC 1841 and ESO-121) whose membership to the Galaxy or LMC is uncertain lie very close to the MP-2. Admittedly, the statistical significance of this configuration is lower than in MP-1 because *a*) only two young clusters are presently members and *b*) Sgr dSph, Arp 2, Terzan 7, and NGC 6715 could be considered as a “single object” since (as noted by the Referee) “they fall on top of one another in partial phase space”.

In Figure 4 we present the same plot as in Fig. 3 but for the MP-2 candidate members. The points form again a clear sinusoidal pattern, strongly suggestive of motion on Keplerian orbits. Note that this configuration is very similar to that shown by Kunkel (1979, Fig. 4) but it provides a remarkably better fit to a *sine* curve and, in addition, it contains both Sgr dSph and the young clusters Arp 2 and Terzan 7.

As for MP-1, also in MP-2 there are objects which can be excluded from a search for young cluster candidates. They are NGC 2808, NGC 2298, and NGC 2419 which are known to be old from their Turn-Off (TO) luminosities (Buonanno *et al.* 1989, VandenBerg *et al.* 1990, Richer 1993). NGC 2419 is moreover the only point significantly deviating from the overall pattern.

The subgroup of MP-2 members which lie close to the Sgr dSph deserves some more comments. Ibata *et al.* (1994) found that NGC 6715, Terzan 7 and Arp 2 are physically neighbours of Sgr dSph and have rather similar radial velocities, and on this basis suggested that they could belong (or have originally belonged) to the Sgr dwarf galaxy. The three clusters and the Sgr dSph are very nicely aligned with respect to the centre of the Galaxy both in space and on the MP-2 plane. Furthermore, following the method introduced by Kinman (1959), we found that they all share clearly plunging orbits. If the deep CCD photometric study of NGC 6715 we are currently carrying on will show that also this cluster is young (like Terzan 7 and Arp 2), the hypothesis of a common origin for the whole sub-group would receive strong support given also the preliminary age estimates obtained for the Sgr dSph, $\simeq 10Gyr$ Mateo *et al.* (1994) (but see Sect. 3.3).

Finally, for completeness, we mention that two more clusters could be somehow associated to this group, *i.e.* Terzan 8 and Pal 8. The available data on them are however still too uncertain to get any reliable indication on their age and kinematics.

### 3.2. Hunting for “young” globulars: IC 4499, a fortuitous alignment or a confirmation?

IC 4499 is a low density southern GGC frequently studied in the past, but only our new photometric study (Ferraro *et al.* 1994) has extended the photometry well below
the TO-region, allowing for the first time an estimate of the cluster age. The mean cluster metallicity derived via different “photometric” indices calibrated in terms of [Fe/H] (i.e. $(B-V)_{0,g}$, $\Delta V$, $S$, $\delta(U - B)_{0,6}$, see Ferraro et al. 1994) turns out to be [Fe/H] = $-1.75 \pm 0.20$ (the error is a conservative estimate), which is lower by at least 0.2 dex than the metallicity measured via other spectroscopic techniques (see Tab. 1). As stressed below, such a discrepancy has been noted in all the young clusters detected so far.

In Figure 5a we present the CMD of IC 4499 containing 7217 stars (variables are not plotted here) down to $V \sim 23$. The measured magnitude difference between the turn-off and the horizontal branch, $\Delta V_{TOHB} = 3.25 \pm 0.15$, is significantly smaller than the mean value of 3.55$\pm$0.09 found by Buonanno et al. (1989) for a sample of 18 well-studied GGCs. This is a clear indication of younger age, and as an example we show in Figure 5b how the CMD ridge line of Arp 2 fits the IC 4499 data. Since Arp 2 is one of the four “young” Galactic globulars detected so far and has a “photometric” metallicity almost identical to that measured for IC 4499, the excellent matching over the entire CMD implies a very similar age, to within 1 Gyr or so. In conclusion, it seems quite proven that IC 4499 is another “young” globular cluster, displaying an age lower by 2-4 Gyr than “normal” clusters having similar metallicities.

Therefore our search based on possible spatial connections between previously known young globulars has apparently been fruitful, since we have found another young globular cluster at less than 2 Kpc from the MP-1 and near the node between MP-1 and MP-2.

### 3.3. Chemical compositions and origin of the young globulars

There are essentially two items worth of consideration in the chemical composition of the young clusters with respect to the other normal clusters: a) the overall metallicities, and b) the possible existence of common peculiarities.

We already discussed the first item in a previous paper (Buonanno et al. 1994a) noting that the young clusters display a very wide metallicity range (from the metal-poor Ruprecht 106 and Arp 2 with [Fe/H] $\sim -1.8$ up to the metal-rich Terzan 7 with [Fe/H] = $-0.49$, Suntzeff et al. 1994). This wide spread is undoubtedly a problem, and in particular it seems difficult to explain how a metal-rich object like Terzan 7 could form in a galactic system (Sgr dSph) having (presently) a quite low mass (similar to the Fornax dSph) and with a mean metallicity less than $-1$ (Ibata et al. 1994, Mateo et al. 1994).

On the other hand, the characteristics of Terzan 7, which is metal-rich, at $\sim 15$ Kpc from the Galactic Centre and $\sim 8$ Kpc from the Galactic Plane, and with a plunging orbit (adopting the framework of van den Bergh 1993), are hardly compatible also with a formation model of a uniformly collapsing proto-Galaxy. One could perhaps think of Terzan 7 as the “nuclear” remnant of a self-enriched larger body now almost totally evaporated or disrupted. However, the fact that its giant branch is so narrow (see
Buonanno et al. 1994a,c) makes any self-enrichment unlikely. Alternatively, it could have been originated by a High Velocity Cloud ejected from the disk of the Galaxy by a supernova-driven “Galactic fountain” (Bregman 1980). This hypothesis could be supported by the fact that old open clusters located at similar galactocentric distances in the disk of the Galaxy display metallicities similar to that of Terzan 7 (Friel 1993). Therefore the cluster would now be infalling on a ballistic orbit. A quite similar scenario could be envisaged also for Pal 8 if the distance and height on the Galactic plane listed by Djorgovski (1993) will be confirmed.

The problem of having galaxies forming globulars more metal-rich than the parent system could be reduced if the cluster metallicity determinations were to be considered differently. In fact, as noted in Sect. 3.2 for IC 4499, a problem apparently always present in analysing the characteristics of the young clusters is that the metallicity determinations obtained from “photometric” methods are systematically lower (by about 0.2-0.3 dex) than the spectroscopic determinations based on the CaII triplet (Da Costa et al. 1992, Suntzeff et al. 1994) (see data in Table 1). The problem is particularly evident for Terzan 7 where Buonanno et al. (1994c) have determined a “photometric” metallicity close to \([\text{Fe/H}] = -1.0\), much lower than the value obtained via “spectroscopic” means. If such a value were confirmed by further observations (or anyway, if \([\text{Fe/H}]\) were significantly smaller than the -0.49 obtained by Suntzeff et al. 1994), since the latest “photometric” estimate of the metallicity of the Sgr dSph population is \([\text{Fe/H}] \sim -1.1 \pm 0.3\) (Mateo et al. 1994), the hypothesis that Terzan 7 and the Sgr dSph could have a physical original connection would get a significant support.

The discrepancy between photometric and spectroscopic metallicity determinations, apart from the noticeable case of Terzan 7, is in general small enough to be accountable for by different reasons in different clusters (e.g. photometric errors, reddening uncertainties, calibration errors of the adopted photometric indices in terms of \([\text{Fe/H}]\), etc.). However, we have investigated if there are intrinsic physical reasons that might cause this discrepancy. One possibility is the effect that a younger age would have on the calibrations, but using the theoretical models by the VandenBerg and the Frascati groups we find that this effect is too small to explain the observed discrepancy (Buonanno et al. 1993, 1994a,b,c, Ferraro et al. 1994). Another possibility is a different abundance ratio in the original material between the typical Milky Way normal clusters and the young ones, which would be in turn a signature of their origin from a different environment. Observations of element ratios are not available yet for these clusters, and are strongly urged for the potentially basic information they may bring on this subject.

As far as the structural and dynamical characteristics are concerned, it is important to recall that: a) all the young clusters detected so far are intrinsically smaller and fainter than the average globular clusters in the Galaxy and, as remarked by van den Bergh (1994b), they show structural characteristics similar to those displayed by the halo clusters of the Magellanic Clouds and of the Fornax dSph; and b) all the five known young globulars (with perhaps the exception of Pal 12) are on plunging orbits,
and two of them (i.e. Ruprecht 106 and IC4499) have prograde rotation, according to the method adopted by Kinman (1959) and van den Bergh (1993).

In conclusion, the origin of the young GGCs (the metal-rich ones, in particular) is not yet understood, but there are increasing hints on a possible connection to episodes of galaxy interactions.

### 3.4 The Andromeda Plane and nodes: just a curiosity?

Before closing this section, it may be interesting to point out another plane whose existence has emerged quite clearly from our tests. This new plane, which we call hereafter the Andromeda Plane, roughly accounts for the Galactic centre, M31 and its satellites and the Magellanic Clouds. As can be seen from the plot in Figure 6, it yields also a fairly good alignment with M33, IC 10 and IC 1613, and, obviously Draco and Ursa Minor. Note that 50% of the certain Local Group members lie within 18 Kpc from this plane. Furthermore, a Kolmogorov-Smirnov test rejects the hypothesis that the considered sample is drawn from a parent population randomly distributed around the plane with a more than 99% confidence level even considering the zone of galactic obscuration, according to Kunkel (1979).

Though it is surely too simplistic to imagine a description of the Local Group galaxies as populating just two or three fundamental planes, it is on the other hand at least puzzling that most (if not all) the galaxies known so far to be members of the Local Group actually lie in or very close to these planes and their respective nodes. This consideration could acquire special relevance if one recalls that several authors (e.g. Valtonen et al. 1993, Byrd et al. 1994 and Lynden-Bell 1993) have already speculated about the occurrence of major interactions between the main members of the Local Group also involving physical complanarities between the Galaxy, M31 and the neighbours non-LG-members IC 342 and Maffei 1, and the possible capture of the MCs from M31.

### 4. ABOUT THE DEFINITION OF “YOUNG” AND ITS IMPLICATIONS

In recent years, there has been a growing consensus on age being the “second parameter” in the outer regions of the Galaxy (Zinn 1993). Though there is, in our view, strong evidence that age cannot be the only second parameter at work (see for instance Fusi Pecchi et al. 1993, Rood et al. 1993, Catelan and de Freitas Pacheco 1994, Buonanno 1994 and references therein), the conclusion that the global formation phase of the Galactic halo lasted longer than originally proposed by Eggen, Lynden-Bell and Sandage (ELS, 1962) or by Yoshii and Saio (1984) seems consistent with the latest observational data and hardly avoidable (Majewski 1993a). Therefore we may assume that in the early stages of the Galaxy formation there has been a rapid (\(\sim 1 \text{Gyr}\)) collapse with accompanying chemical evolution of a large protogalactic cloud producing the bulk of the old halo and disk clusters, followed by a (chaotic) merging over several Gyrs of
multiple fragments that experienced independent chemical evolution. The attention is now mostly focused on identifying which clusters (or group of clusters) belong to a given population or to a given original “fragment” (Searle and Zinn 1978).

Following the very valuable approaches of Zinn and collaborators and van den Bergh, the basic tools used so far for this purpose are essentially the HB morphology as age indicator, and the present Galactocentric location and radial velocity as indicators of the kinematical properties. Several studies (see in particular Rodgers and Palouglo 1984, Zinn 1993, van den Bergh 1993, 1994b, Majewski 1994) have also led to identify specific sub-groups of clusters which could share common original properties. However, it is important to note that the definition of “young” based on the HB morphology may be ambiguous if age is not the only second parameter driving the star distribution along the HB. Also the true kinematical properties are actually unknown until complete space velocities will be precisely measured.

In this sense, our definition of “young” globular cluster is different from that used for instance in the Zinn’s terminology, as we rest on the actual measure of the TO luminosity. The reason why we think this note is important can be seen, for instance, with respect to the very interesting results presented by Majewski (1994).

Very schematically, Majewski (1994) reports that the group of the 10-13 reddest HB, young halo clusters in the Zinn list appear to populate the FLS plane suggesting a scenario where the FLS stream and the red-HB young halo globular clusters share a common origin from a large fragment à la Searle and Zinn or from a former parent satellite galaxy. Based on the list presented in Table 1 of Majewski (1994) one may notice however, that the 10 clusters with the HB parameter taken from Lee et al. (1993) $(B - R)/(B + V + R) < -0.5$ (i.e. with red HBs) display a wide range of relative ages when the MS and TO regions are considered. In particular, Pal 12 and Ruprecht 106 are surely younger than normal clusters by 3-4 Gyr based on their TO properties, whereas NGC 1261 and 2808 have normal ages (at least as far as the available TO data indicate, see Bolte and Marleau 1989, Buonanno et al. 1983, respectively). Moreover, they span a very wide range in Galactocentric distances ranging from $\sim$ 8 to $\sim$ 110 Kpc, and quite different types of orbits (at least in the framework of van den Bergh 1993). If one extends the sample to the 13 clusters with $(B - R)/(B + V + R) < -0.3$, the situation is even worse as one would mix clusters with known prograde and retrograde orbits. Therefore, given the spread of observed properties, a “single-event” common origin for this group seems quite unlikely, as it would require a fairly large fragment with very special conditions of orbit decaying. The internal inconsistencies of the scenario which makes use of any HB parameter as age indicator was pointed out also in the Majewski’s paper (Fig. 4 and note 5), where he finds that the clusters displaying the largest $\Delta(B - R)/(B + V + R)$ (i.e. the parameter more directly correlated to age differences, Zinn 1993) do not correlate with the FLS plane as significantly as the red-HB clusters do.
On the other hand, though necessarily not very significant on statistical grounds given the very small number of involved objects, interesting hints can be found considering subsets of the clusters singled out by Majewski (1994) or others. For instance, Pal 4, Pal 14, Eridanus, and (slightly worse) Pal 3 lie in a plane including the Galactic Centre, are very distant (far beyond the $33 - 60 \text{Kpc}$ radial gap noted by Zinn (1985) in the GGC distribution), are faint and morphologically similar, span a small metallicity range, lie all on plunging orbits. So, for what our analysis is concerned, the major hints about “common-origin groups” favours small scale phenomena rather than the single-event accretion of large fragments, comprehensive of $8 - 10$ globulars, as envisaged by Majewski (1994) or van den Bergh (1993).

In conclusion, though the various claims (including our own) of possible families of globular clusters born from a common proto-fragment are attractive and worthy of further detailed studies, it may be wise to wait for an extended survey of the TO-properties of the considered globulars, at least until the second parameter problem is definitely settled, before accepting oversimplified models of Galaxy formation. Furthermore, it is worth noting that different proposed scenarios (for example recent capture from still existing systems, primordial merging of self-enriched fragments, or formation induced by close dynamical interactions between galaxies) are not equivalent and none of them can be presently ruled out on observational basis. Crucial in this respect is the determination of mass of the fragment(s)/galaxy which eventually merged into the Milky Way, as this will pose very strong constraints on the formation/destruction of the thin and thick disks of our own Galaxy (Quinn et al. 1993). In our view, there is presently no clear-cut observational evidence against a model of Galaxy formation of the type “main collapse” à la ELS + “noise” à la SZ, provided that a slightly longer timescale for the main collapse event ($\sim 1 - 2 \text{Gyr}$, Sandage 1993) is adopted.

5. CONCLUDING REMARKS

The basic aim underlying the present study is the definition of a procedure able to yield, first, possible candidate young globular clusters and, second, a global scenario which could somehow link the origin of these young clusters to past interactions between the Milky Way and its satellites.

This task has been carried out by looking for spatial configurations involving both clusters and galaxies and following the approach used in the early ’70s for instance by Kunkel, Demers and Lynden-Bell to suggest the existence of a few Great Circles (the Magellanic Plane and the Fornax-Leo-Sculptor Plane) which ideally contain various (GGCs and galaxies) satellites of the Milky Way.

The main conclusions of the present report are:

1. We present two planar configurations which link the young globular clusters detected so far in the Milky Way to its satellites. In particular, one of them –MP-1–
connects Pal 12 and Ruprecht 106 to SMC and The Magellanic Stream, supporting the hypothesis of a “magellanic origin” for these two cluster (Lin and Richer 1992).

2. Using the present approach, we found another candidate young globular cluster, IC 4499, lying on MP-1: so three over five of the presently known young Galactic globulars are apparently aligned on MP-1 and display kinematical properties compatible with that of other MP-1 members. This cannot be taken yet as a proof of (hysterical) physical connections, but may be worth of further study.

3. While discussing about the detection and origin of the young globular clusters, we present some warnings and comments about the need for a clear-cut definition of the term “young” here based on the Turnoff properties whilst it is generally used also adopting the Horizontal Branch morphology as a safe age-indicator (Lee 1993, Zinn 1993). In particular, we show that this may lead to rather implausible identifications of subgroups of clusters whose common origin is envisaged.

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Figure Captions:

**Figure 1:** The Galactocentric Great Circles representing the Magellanic Plane (*MP, full line*) and the Fornax-Leo-Sculptor Plane (*FLS, dotted line*), respectively. The coordinates are Galactocentric Galactic longitude and latitude, in degrees. Labels are abbreviated names or NGC numbers. The patterns at the low corners of the plot are schematic representations of the Magellanic Stream according to Kunkel (1979).

**Figure 2:** The MP-1 (*dashed line*) and MP-2 (*full line*) Galactocentric Great Circles (see Sect. 3.1) in the same coordinate system as in Fig. 1. The planes are constrained to pass through the Galactic Centre. Note that the MP-2 nearly fits the extension of the Magellanic Stream.

**Figure 3:** Radial velocities of MP-1 members, corrected for both LSR and solar motions, as a function of the orbital longitude. The *full line* represents a first order fit to the data of the Equation 1 of Kunkel (1979).

**Figure 4:** Radial velocities of MP-2 members, corrected for both LSR and solar motions, as a function of the orbital longitude. The *full line* represents a first order fit to the data of the Equation 1 of Kunkel (1979).

**Figure 5:** a) The Color Magnitude Diagram of the Galactic globular cluster IC 4499, lying on the MP-1; b) the mean ridge line of Arp 2 superposed on the IC 4499 data. As can be deduced from the nice fit in the Turnoff region, the age of the two clusters is the same to within 1 Gyr (see Sect. 3.2).

**Figure 6:** The Andromeda Plane (see Sect. 3.4) plotted in the same coordinate system as in Fig. 1 and 2. Note that ~ 50% of the galaxies which are certain members of the Local Group are located within 18Kpc from this plane. A zoomed plot of the region surrounding M31 is also presented: the alignment of galaxies in this region is rather striking.
Table 1. Metallicities of the Young G.C.: spectroscopic vs. photometric.

| Name   | $[\text{Fe/H}]_{\text{phot}}$ | Ref   | $[\text{Fe/H}]_{\text{spec}}(\text{CaII})$ | Ref   |
|--------|-------------------------------|-------|--------------------------------|-------|
| Terzan 7 | $-1.00 \pm 0.13$ | B94c  | $-0.49 \pm 0.05$ | S94   |
| IC 4499 | $-1.75 \pm 0.20$ | F94   | $-1.5 \pm 0.3$ | ZW84  |
| IC 4499 | $-1.77 \pm 0.20$ | W85   | $-1.38 \pm 0.2$ | Sm84  |
| Rup 106 | $-1.90 \pm 0.20$ | B90   | $-1.69 \pm 0.05$ | DAN   |
| Rup 106 | $-1.85 \pm 0.20$ | W85   |                       |       |
| Rup 106 | $-1.61 \pm 0.20$ | Sa94  |                       |       |
| Arp 2   | $-1.84 \pm 0.25$ | B94b  | $-1.73 \pm 0.05$ | S94   |
| Arp 2   | $-1.85 \pm 0.20$ | W85   |                       |       |
| Pal 12  | $-1.13 \pm 0.20$ | W85   | $-0.60 \pm 0.11$ | AD91  |
| Pal 12  | $-1.06 \pm 0.12$ | DA90  | $-1.0 \pm 0.1$ | AD91  |
| Pal 12  | $-0.98 \pm 0.14$ | Sa94  |                       |       |

AD91 = Armandroff & Da Costa 1991; B90 = Buonanno et. al. 1990; B94b = Buonanno et. al. 1994b; B94c = Buonanno et. al. 1994c; DA90 = Da Costa & Armandroff 1990; DAN = Da Costa, Armandroff & Norris 1992; F94 = Ferraro et. al. 1994; Sa94 = Sarajedini 1994; S94 = Suntzeff et. al. 1994; Sm84 = Smith 1984; W85 = Webbink 1995; ZW84 = Zinn & West 1984.