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High relative velocity central dumbbells in poor clusters*

H. Quintana[1,**], **D. Proust**[2], **G. Hertling**[1], **A. Ramírez**[3], **I. Toledo**[1], and **M.J. Way**[4]

[1] Pontificia Universidad Catolica de Chile, Department of Astronomy and Astrophysics, Casilla 306, Santiago, Chile
[2] Observatoire de Paris – Section de Meudon, F92195 Meudon CEDEX, France
[3] Departamento de Fisica, Universidad de La Serena, La Serena, Chile
[4] NASA Ames Research Center, California, USA

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We propose that some high relative velocity dumbbell galaxies are the centers of poor clusters or groups that are coming into a merging process. The components of these galaxies closely follow the incoming velocity of the merging groups, as revealed by the bimodality of the velocity histograms. Only mergers in a direction with a small angle to the line of sight can show the large velocity difference of the components and the velocity separation of incoming subgroups in the histograms. In this case the simple interpretation would be that the dumbbells components are also in an early phase of their merger, as they still keep the information of the incoming orbits, but analysis of a numerous sample is needed to prove this suggestion.

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1 Introduction

Dumb-bell galaxies are a pair of gravitationally interacting E galaxies of similar magnitudes, that show gravitational interactions from tidal distortions, common haloes and/or bridges. If the galaxies are bound, the process will lead to a merger, in a time scale of 2–3 galaxy crossing times. Many dumb-bells are the brightest central member galaxies (BCM) in rich clusters, with typical relative velocity difference between components of order of a few hundred $\mathrm{km\,s^{-1}}$. The geometry of the orbits will control the time to merge: short times for radial or highly elliptical orbits, longer times for circular orbits (Valenjtin & Casertano 1988). It could be expected that a dumbbell merge will produce a single elongated cD galaxy. In fact, originally these BCM dumb-bells are classified as cDs (Mathews, Morgan & Schmidt 1964).

Two straightforward interpretations of the origin of the two members of the BCM dbs can be given:

- Two of the brightest elipticals in the cluster get to the center (dynamical drag or other effect), where they are forced to interact, eventually producing a cD.
- The two similar E are the brightest members of merging clusters, each originally near its own cluster center. Mergers of cluster are expected to occur with small impact parameter, so both BCM get close, form a dumbbell, and later, a cD with large ellipticity (present in most cDs). In this case, the presence of a BCM db would be a telling sign of an ongoing merger.

When the dumbbell galaxies are "isolated" and the relative velocity is high, as is the case of the pair NGC4782/3, it has been interpreted as elliptical galaxies in an hyperbolic, unbound, orbit (Borne, Balcells & Hoessel 1986; Borne & Colina 1993). However, Quintana, Ramírez & Way (1996) also suggested that this system is the central dumbbell of a group, where two subgroups are in collision and, quite likely, in a merging process.

We have identified a few systems with prominent central dumbbells, whose components have an unusually high relative velocity. What is the origin of central dbs in clusters when the relative velocity is significant ($\geq$500 $\mathrm{km\,s^{-1}}$)? Are these galaxies in unbound orbits? Or is the high velocity related to the collision velocity of two clusters involved in a merging process? Even with a fairly high relative velocity two galaxies could be bound if they are near the center inside the deep potential well of a merging cluster, that suffers a process of violent relaxation. Is this also a feasible interpretation in poor clusters, such as those discussed below? In fact, if the mergers are proceeding at low velocity or in a direction close to the plane of the sky, it is very hard to verify that a merger is underway by the analysis of the velocity distribution (whereas an X-ray analysis provides the answers). But if the relative velocities are high, because mergers are occurring in a direction close to the line of sight, the histogram of the velocities can show bimodality thus pointing to an ongoing merger.

2 Data and mergers on two dumbbell clusters

Here we present velocity data on the two poor Abell S clusters A0897S and A0574S (Abell, Corwin & Olowin 1989),

* Data taken at Las Campanas Observatory
** Corresponding author: hquintana@astro.puc.cl

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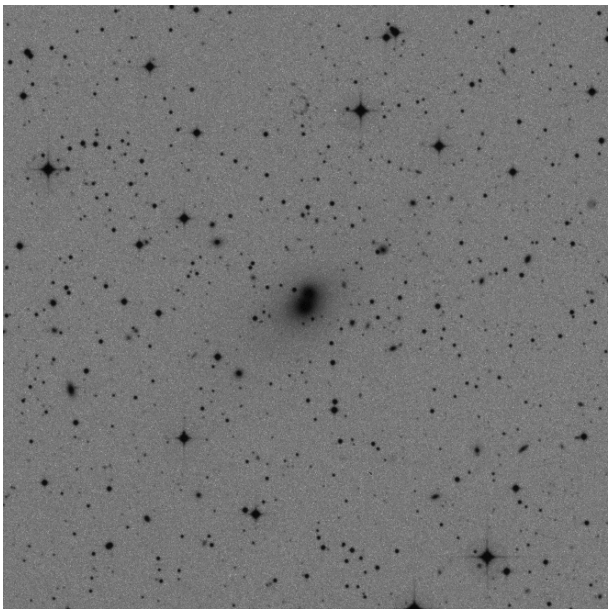

Fig. 1 The A0897S cluster central region (an area 15×15 arcmin reproduced from the Sky Survey). The outstanding dominant character of the dumbbell is apparent as well as the tidal halo distortions of both components.

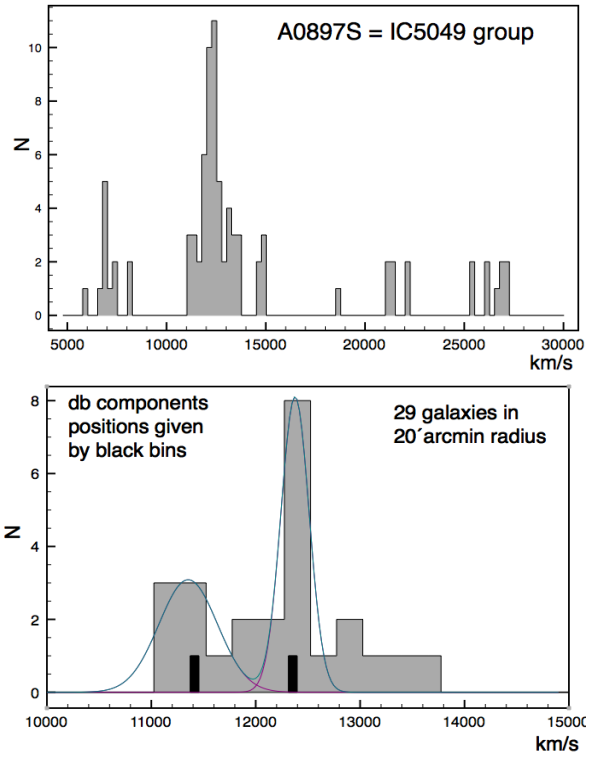

Fig. 2 *Top*: histogram of 101 velocities in A0897S = IC5049 group. *Bottom*: histogram of 29 velocities in the range 10 000–14 000 km s^{-1} and in a 20 arcmin radius. The black bars show the position of the dumbbell components. A two Gaussian fit is shown. Bin size = 250 km s^{-1}.

where the relative velocity between components is ≥500 km s^{-1}. We also review the NGC4782/3 group. These two examples were selected for further study from an original catalog of southern dumbbells built by visual inspection of the Sky Survey plates (Ramírez et al. 2010). We measured many new redshifts and component velocity differences for dumbbell entries in the catalog, from which we identified interesting high velocity components. All the data presented in this paper has been obtained as backups programs of other cluster projects (when primary targets were unreachable, which is the reason of the selection of the right ascension positions of both clusters).

2.1 The NGC 4782/3 group summarized

The NGC 4782/3 pair has a long history in the literature (see Machacek et al. 2007). Its first analysis as a group was done by de Souza & Quintana (1990), with a more complete dynamical discussion by Quintana et al (1996), based on 124 observed velocities, 35 of which were in the velocity range of the group and within 35 arcmin (0.65 Mpc radius) of its center. The two dumbbell components have a velocity difference of 670 km s^{-1}, each centered on a two Gaussian fit to the bimodal velocity histogram (however poor membership statistics limits this analysis). Recently, Machacek et al. (2007) discussed its X-ray, radio and jets properties. The X-ray data shows NGC4783 falling onto the massive group around NGC4872. Nevertheless, a small group associated to NGC4783 could be present in our velocity data, perhaps not with enough hot gas to show. From the X-ray temperature relation, a total mass of 4.8×10^{13} $M_\odot$ was derived, consistent with the large 447 km s^{-1} velocity dispersion when taken as a single group (very large for a group).

2.2 The dumbbell cluster A0897S

The cluster A0897S (or the IC5049 group) is a BM type I, regular cluster, with richness class 0 and distance class 4, really located at a redshift of $z = 0.04$. The central interacting pair IC5049 has an outstanding dominance on the cluster members, as seen in Fig. 1. The relative velocity of their dumbbell components is 940 km s^{-1}.

Velocities of 101 galaxies, in an area of 1.5°×1.5°, were obtained between 1988–2006 at the Dupont (2dfrutti and fiber spectrographs) and Magellan telescope (LDSS2 spectrograph) of the Las Campanas Observatory. Inside 20 arcmin of the center (1 Mpc) there are 29 velocities between 10 000 km s^{-1} and 14 000 km s^{-1}. The dumbbell components velocities are 11 414 km s^{-1} and 12355 km s^{-1} (± 30 km,s^{-1}), with a difference of 940 km s^{-1}. The top histogram in Fig. 2 shows the distribution of velocities in the field. The cluster is well separated from other velocity structures. The bottom histogram of the 29 cluster velocities in the central region shows a bimodal distribution, with one richer subsystem. A 2 Gaussian fit is also shown, with peaks near the velocities of the dumbbell components. The projected galaxy distribution does not show any strong spatial

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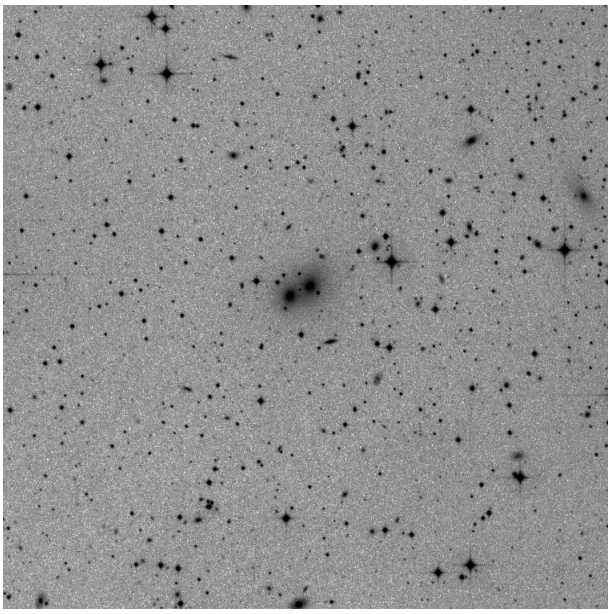

Fig. 3 The A0574S cluster central region (an area 15×15 arcmin reproduced from the Sky Survey). The dominant character of the dumbbell is apparent as well as tidal distortions of the haloes of both components. Some of the other bright galaxies are non-members.

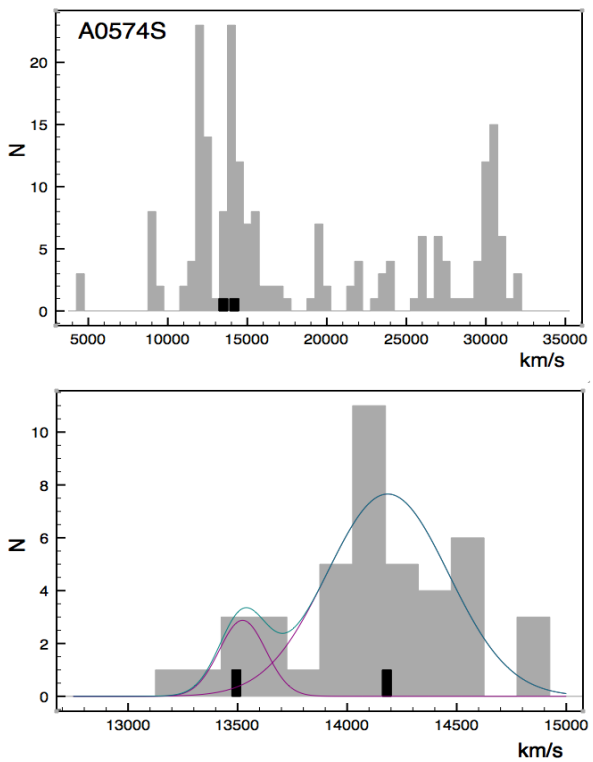

Fig. 4 *Top*: histogram of 213 velocities in A0574S region – area of 2.4°×2.4°. Bin size = 500 km s^{-1}. *Bottom*: histogram of velocities in the range 11 000–15 000 km s^{-1} in a 1.25 Mpc projected radius. The black bars show the position of the dumbbell components. A two Gaussian fit is shown. Bin size = 160 km s^{-1}.

asymmetries, consistent with an ongoing merger at a small angle to the line of sight.

2.3 The dumbbell cluster A0574S

The cluster A0574S is also a BM type I, classified as Irregular, with richness class 0 and distance class 3. We measured a redshift of $z = 0.44$. The close projections of the clusters A0566S (at a mean velocity difference of only 2100 km s^{-1} and 75 arcmin to the West) and A0576S produces the apparent irregular spatial distribution of galaxies. The central dumbbell ESO-254-IG037 (Fig. 3) has a SE component at a redshift of 13 494 km s^{-1} ± 33 km s^{-1} and the NW component at 14 181 km s^{-1} ± 100 km s^{-1}. The relative velocity of both dumbbell components is 700 km s^{-1}.

Here we report 167 spectra obtained in two exposures with the fiber spectrograph, plus 14 single slit exposures with the WFCCD spectrograph, at the Dupont telescope at Las Campanas Observatory. Additionally, from NED we recovered 47 velocities for other galaxies. In Fig. 4 we show the histogram of all velocities in an area of 2.4°×2.4°, or a projected 7×7 Mpc at the cluster, which reveals a complex velocity field due to the presence of foreground and background structures (particularly A0566S). A0574S is limited between 13 000 km s^{-1} and 15 000 km s^{-1}, velocities shown at the bottom of Fig. 4, taken from an area 43 arcmin in diameter (or 2.5 Mpc).

The histogram of the cluster members show again a bimodal nature, with each dumbbell component near the center of each clump. This is consistent with two groups or small clusters coming into a merger process. Recently acquired observations, to be reported in a future publication, will increase the number of members with velocities to improve the statistics in order to sharpen the definition of each subgroup and calculate separate masses.

3 Conclusions

In all three examples, the merger involves a more massive cluster and an incoming group with a very dominant elliptical. Also, in all three cases, the dominance of the dumbbell components is remarkable (and is a bias in their selection). The high dumbbell components relative velocities are correlated to their respective groups or subclusters mean velocities. We are able to identify these substructures precisely due to the high relative velocity that makes the bimodality of the histogram detectable. Thus, these high velocity dumbbells show the presence of group/poor cluster mergers. Conversely, the merger also clarifies the reason these interacting pairs of elliptical galaxies have so high relative velocities. Moreover, the velocity positions of the dumbbell components is nearly centered on the dispersion of their respective groups. Thus, these galaxies have not lost the information of their incoming merging velocities. That is to say, they are in the first passage around the other elliptical galaxy (or at half an orbit later or, in principle, on similar orbital phases, when the relative velocity along the line of

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sight is near maximum). Here we do not have enough systems to analyze the statistics of the orbits. With a large sample of similar systems, if the dumbbells had nearly circular orbits, we should be able to see a wide range of projected velocities between components, in contrast to the merging subclusters which will keep for a longer time their large initial difference. An analysis of a larger number of these high velocity dumbbell systems can help to establish the relation between dumbbells and mergers. The study of the presence of gas, as detected by X-rays, will also provide an excellent tracer of the subgroups state in the mergers.

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References

Abell, G.O., Corwin, Jr., H.G., Olowin, R.P.: 1989, ApJS 70, 1
Borne, K.D., Balcells, M., Hoessel, J.G.: 1988, AJ 333, 567
Borne, K.D., Colina, L.: 1993, ApJ 416, 157
de Souza, R., Quintana, H.: 1990, AJ 99, 1065
Machacek, M.E., Kraft, R.P., Jones, C., Formaan, W.R., Hardcastle, M.J.: 2007, ApJ 664, 804
Mathews, T.A., Morgan. W.W., Schmidt. M.: 1964, ApJ 140, 35
Quintana, H., Ramírez, A., Way, M.J.: 1996, AJ 111, 603
Ramírez, A., et al.: 2010, in preparation
Valentijn, E.A., Casertano, S.: 1988, A&A 206, 27

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