GALAXY ORIENTATIONS IN THE COMA CLUSTER

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ABSTRACT

We have examined the orientations of early-type galaxies in the Coma Cluster to see whether the well-established tendency for brightest cluster galaxies to share the same major-axis orientation as their host cluster also extends to the rest of the galaxy population. We find no evidence of any preferential orientations of galaxies within Coma or its surroundings. The implications of this result for theories of the formation of clusters and galaxies (particularly the first-ranked members) are discussed.

Subject headings: galaxies: clusters: individual (Coma) — galaxies: elliptical and lenticular, cD — galaxies: evolution — galaxies: formation — galaxies: fundamental parameters — large-scale structure of universe

1. INTRODUCTION

It has long been known that the major axis of central cluster galaxies tends to be aligned with the major axis of the cluster galaxy distribution and to point toward similar structures on scales of typically a few tens of Mpc (e.g., Binggeli 1982; West 1989; Trevese et al. 1992; Fuller et al. 1999; Plionis et al. 2003 and references therein). The most likely mechanism for the origin of this “alignment effect” invokes collimated infall of galaxies along the filaments that make up the large-scale structure in which clusters are embedded and from which clusters grow (West 1994; Dubinski 1998), suggesting a connection between the growth of the clusters and the formation of their massive dominant galaxies (e.g., Faltenbacher et al. 2005).

It is unclear whether fainter cluster galaxies should show the alignments that are expected (and observed) for the first-ranked members. Clusters and galaxies are believed to form through a process of hierarchical accretion. In these models, predictions for isotropy (or deviations) of galaxy position angles are not well defined (West et al. 1991), but the consensus seems to be that any primordial alignments would be quickly erased by dynamical interactions (Coutts 1996; Plionis et al. 2003). Conversely, it is expected that groups and clusters show preferential alignments in the direction of the last major accretion episode (Faltenbacher et al. 2005). Searches for alignments among the fainter cluster galaxies have generally returned ambiguous results, with some positive detections (Djorgovski 1983; Plionis et al. 2003; Aryal & Saurer 2006) as well as null results (Dekel 1985; Godlowski & Ostrowski 1999; Strazzullo et al. 2005; Aryal et al. 2006). However, it is possible that the presence of anisotropy in position angles can only be detected in less evolved clusters (Plionis et al. 2003), while it is also conceivable that only near neighbor galaxies are aligned with each other because they exert reciprocal tidal torques (Kitzbichler & Saurer 2003), or that radial alignments are induced by the cluster tidal field (Pereira & Kuhn 2005).

With this in mind, we reexamine the issue of isotropy in galaxy position angles in the Coma Cluster. We use a unique multicolor optical-infrared CCD mosaic of the inner 750 h\(^{-1}\) Mpc of this cluster and, within this region, a complete (magnitude limited to \(H < 14.5\)) sample of 111 spectroscopic members plus 77 additional fainter members. Most previous work has relied on photographic plates and identified cluster members statistically or via the red sequence. The results we present in the following are most consistent with an isotropic distribution for galaxy position angles, other than for the two brighter members. We then explore the implications of these findings for the formation of clusters and their members, particularly with regard to the brighter central cluster galaxies.

2. DATA ANALYSIS

We use the UBVRizJHK images of the core of the Coma Cluster and the catalog published by Eisenhardt et al. (2007), which includes photometry and a compilation of spectroscopy from the literature. The spectroscopic sample of Coma galaxies is complete to \(H = 14.5\), and less so for fainter magnitudes.

Galaxy major-axis position angles and ellipticities were measured using Source Extractor (Bertin & Arnouts 1996). Measurements obtained independently from \(U, V,\) and \(K\) images were compared and found to be similar; consequently only the \(V\)-band images were used for further analysis. We verified the SEXTRACTOR position angles by isophotal modeling of the galaxies using IRAF ELLIPSE and also by comparing with the isophotal position angles from the SDSS (York et al. 2000; Stoughton et al. 2002). The values produced by SEXTRACTOR are in good agreement with the measurements from IRAF ELLIPSE and the SDSS position angles, except for a few objects with small ellipticities.

We tested the observed distribution of position angles against a uniform distribution using the Kuiper test. Figure 1 shows the results of this comparison: we find no significant deviation from isotropy. This holds if we limit our sample to galaxies with larger ellipticity or to the brighter members (e.g., West 1998). Subsamples of galaxies with ellipticities \(e > 0.1, 0.2,\) and 0.3 were examined, containing 128, 94, and 61 galaxies, respectively, but in all cases no preferred orientations were found. Likewise, culling the sample of galaxies to those brighter than \(H = 11, 12,\) and 13 (10, 33, and 58 galaxies, respectively) also yielded a null detection of position angle anisotropies.

While the above constitutes strong evidence that there are...
no large-scale galaxy alignments (other than for the brightest cluster galaxies), we now consider whether there are alignments between nearest neighbors (in projection) due to reciprocal tidal torques (Kitzbichler & Saurer 2003), or due to the presence of substructure whose members are aligned with each other (Plionis & Basilakos 2002). The result of this test is shown in Figure 2, where we find no significant deviation from isotropy.

3. DISCUSSION

The results of the analysis presented above are consistent with random orientations of the position angles of Coma galaxies, with the possible exception of the two brightest cluster members, NGC 4889 and NGC 4874, whose major-axis position angles are quite similar to that of the cluster’s galaxy and X-ray gas distributions (West & Blakeslee 2000). The line connecting the two galaxies is also aligned with the galaxy and X-ray gas distributions, as also found by Trevese et al. (1992). While this is consistent with the null results found for some clusters, there are other objects for which significant alignments are detected. Possibly the clearest case is Abell 521 (Plionis et al. 2003), which shows detectable alignments out to 5 h⁻¹ Mpc. This cluster is known to be dynamically young and to show considerable substructure (Ferrari et al. 2006). Coma, on the other hand, is not a fully relaxed cluster and shows substructure...
in the X-ray gas and in the position-velocity distribution of its members (e.g., Adami et al. 2005), but it is clearly (comparatively) more evolved than either A521 or Virgo, where there is also evidence of a nonisotropic distribution of galaxy alignments (West & Blakeslee 2000). As suggested by Plionis et al. (2003), the lack of alignments in Coma may be due to its more advanced state of dynamical evolution with respect to other clusters (see, e.g., Aryal & Saurer 2006). However, Ciotti & Dutta (1994) predict that galaxy alignments will result as galaxies interact with the cluster tidal field, on relatively short timescales. Coma might be in the situation in which original alignments have been erased but the cluster has not sufficiently relaxed to permit the tidal field to create new alignments.

In order to test this, we considered galaxy alignments in the filaments that connect Coma to the large-scale structure toward A1367 and A2197/A2199 (Fig. 3). We retrieved these data from the SDSS and tested for position angle anisotropy. All galaxies with available data were used, irrespective of their magnitudes. Because complete SDSS spectroscopy is not available for this region, redshifts were taken from the NASA Extragalactic Database and the sample of galaxies restricted to those with velocities in the range 4000–10,000 \( \text{km s}^{-1} \) expected for Coma and its environs. Here too, however, we find no evidence for any significant deviations from isotropy for filament galaxies (Fig. 4). This suggests either that these galaxies formed without any preferred orientations, or that any alignments that might have existed are quickly erased even in low-density regions. In this context it is not surprising that alignments can be detected more clearly in A521 and Virgo, two clusters that appear to have been recently formed from the coalescence of numerous small groups.

The main inference we can draw from this study is that the first-ranked cluster galaxies are special in yet one more way. Unlike all other cluster galaxies, they appear to have undergone
a peculiar formation mechanism, related to collimated infall and the growth of the cluster from the surrounding large-scale structure, and resulting in the observed alignment effects. All other galaxies appear to have had a more random merger history. While fainter galaxies may have been accreted to the cluster at later epochs, thus explaining the lack of alignments, the brightest cluster member may have been the kernel around which clusters originally formed.

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REFERENCES

Adami, C., Biviano, A., Durret, F., & Mazure, A. 2005, A&A, 443, 17
Aryal, B., Kandel, S. M., & Saurer, W. 2006, A&A, 458, 357
Aryal, B., & Saurer, W. 2006, MNRAS, 366, 438
Bertin, E., & Arnouts, S. 1996, A&AS, 117, 393
Binggeli, B. 1982, A&A, 107, 338
Ciotti, L., & Dutta, S. N. 1994, MNRAS, 270, 390
Coutts, A. 1996, MNRAS, 278, 87
Dubinski, J. 1998, ApJ, 502, 141
Dekel, A. 1985, ApJ, 298, 461
Djorgovski, S. 1983, ApJ, 274, L7
Eisenhardt, P. R., De Propris, R., Gonzales, A., Stanford, S. A., Wang, M. C., & Dickinson, M. E. 2007, ApJS, 169, 225
Faltenbacher, A., Allgood, B., Gottlöber, S., Yepes, G., & Hoffman, Y. 2005, MNRAS, 362, 1099
Ferrari, C., Arnaud, M., Ettori, S., Maurogordato, S., & Rho, J. 2006, A&A, 446, 417
Fuller, T. M., West, M. J., & Bridges, T. J. 1999, ApJ, 519, 22
Godlowski, W., & Ostrowski, M. 1999, MNRAS, 303, 50
Kitzbichler, M. G., & Saurer, W. 2003, ApJ, 590, L9
Pereira, M. J., & Kuhn, J. R. 2005, ApJ, 627, L21
Plionis, M., & Basilakos, S. 2002, MNRAS, 329, L47
Plionis, M., Benoist, C., Maurogordato, S., Ferrari, C., & Basilakos, S. 2003, ApJ, 594, 144
Stoughton, C., et al. 2002, AJ, 123, 485
Strazzullo, V., Paolillo, M., Longo, G., Puddu, E., Djorgovski, S. G., De Carvalho, R. R., & Gal, R. R. 2005, MNRAS, 359, 191
Trevese, D., Cirimele, G., & Flin, P. 1992, AJ, 104, 935
West, M. J. 1989, ApJ, 344, 535
———. 1994, MNRAS, 268, 79
———. 1998, in Untangling Coma Berenices, ed. A. Mazure et al. (Singapore: World Scientific), 36
West, M. J., & Blakeslee, J. P. 2000, ApJ, 543, L27
West, M. J., Villumsen, J. V., & Dekel, A. 1991, ApJ, 369, 287
York, D. G., et al. 2000, AJ, 120, 1579