Position Angle Distribution of Galaxies in 35 Cluster

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Abstract : *We worked on POSSII and ESO films and measured the diameters and position angles of 5 688 galaxies in 34 clusters using 25-fold magnification microscope. The position angle distributions of galaxies in the clusters are studied. For this, chi-square, auto-correlation and the Fourier tests are carried out. The preferred position angle distribution of galaxies in the cluster is found to be independent of the mean radial velocity of the cluster. Possible explanations of the result will be discussed.*

Keywords: galaxies: evolution, galaxies: formation, galaxies: statistics, galaxies: clusters: general

1. INTRODUCTION

Galaxy clusters are generally not in dynamical equilibrium (Peebles 1988). They hadn't been enough crossing times since they formed. They are much bigger on the sky and thus have many more background objects to lens. Their mass distributions and lensing potentials are thus warped in more complicated ways than a single galaxy (Barkanan & Loeb 2003). Argyres (1986) reported that the populations of galaxies are systematically higher in the direction of the major axes of the brightest galaxy in rich clusters. Adams, Strom & Strom (1980) studied seven Rood-Sastry L-type Abell clusters and found a week tendency of the galaxy position angle (PA) to concentrate along the cluster PA and perpendicular to it. Macgillivary & Dodd (1979a, 1979b, 1985) investigated several groups and clusters and found a weak tendency of galaxies to be aligned with, or perpendicular to, their radius vectors to the cluster or group center. Godwin et al. (1983) published machine measurements of 6 727 galaxies in the Coma region. Djorgovski (1983) analyzed their data and observed prominent alignment effects. He found that galaxies tend to align in the east-west direction with a high degree of significance. Strom & Strom (1978) studied the Perseus-Pisces Supercluster and noticed a distinct preference of the elliptical to align with the main cluster chain. Gregory et al. (1981) noticed alignments and perpendicularity at a larger scale in the Perseus-Pisces Supercluster. Thompson (1976) noticed a tendency for galaxies in Coma to point towards the cluster center.

The preferred inclination and PAs of galaxies in clusters and their relations to the cluster redshift might be important in order to understand the mass distribution in the cluster. We present an analysis of the inclination and PA of 5,688 galaxies in 34 clusters and discuss their relations to the cluster mean radial velocity (RV). The data and method of analysis are described in sections 2 and 3. Results will be presented in the section 4. Finally, a discussion of the statistical analysis, previous results and conclusions are given in sections 5, 6 and 7.

2. DATABASE

A cluster had to fulfill the following selection criteria in order to be selected: (1) the clusters had to have an Abell richness (R) >1, (2) the RV of the cluster should be known, and (3) the morphology of the cluster should be given. There were 107 clusters in the ACO (Abell et al. 1989) catalogue fulfilling the selection criteria. We inspected all these clusters on the film copies (red sensitive ESO/POSS II) with the aid of a binocular microscope, and selected 34 of them. The reasons for the selection were: (1) the galaxies in these clusters were not too faint and it was relatively easier to determine diameters and PAs of many galaxies with relatively great accuracy, and

(2) the Galactic contamination in and around the clusters was minimum, and (3) films were available.

The search for galaxies was performed on the red sensitive ESO (l_{eff} = 640 nm) and POSSII films (l_{eff} = 640 nm) having a limiting magnitude of m_{lim} = 20m. The compilation of the catalogue consisted of six steps: (1) Inspection of each film of interest by eye. (2) Re-examination of all objects detected in step 1. (3) Determination of the major (a) and minor (b) diameters of each galaxy candidate. (4) Measurement of PA of each galaxy candidate. (5) Measurement of the position of each object. (6) Comparison of the final galaxy sample to known galaxies.

Each ESO and POSSII film-copies of interest were scanned by eye. This was performed by the aid of a binocular microscope with a 25-fold magnification. The film-copies were illuminated from below. The criteria an object had to fulfill in order to be selected were: It had to show a diffuse, non-stellar appearance and a diameter (a) of >10 arcsec. The objects fulfilling these criteria were marked on transparent foils attached on the films. The second step was the re-examination of the objects selected in step 1. Re-examination resulted the rejection of more than 20% of the objects. The remaining candidates were marked with a circle in the film for clear extragalactic identification.

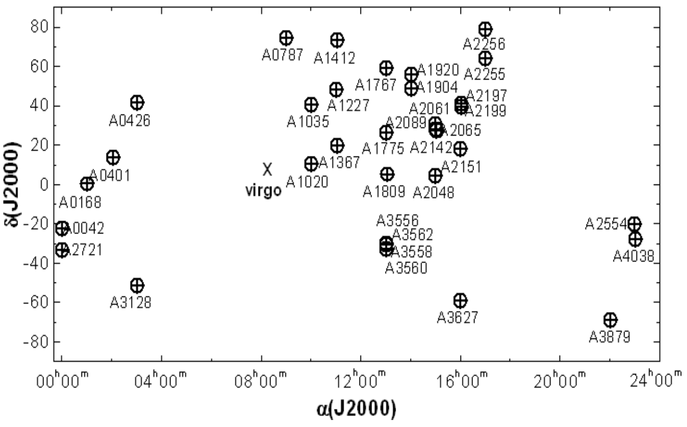
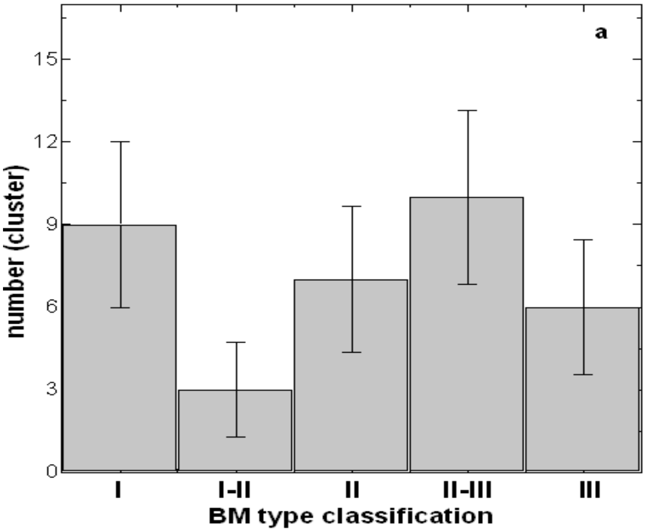
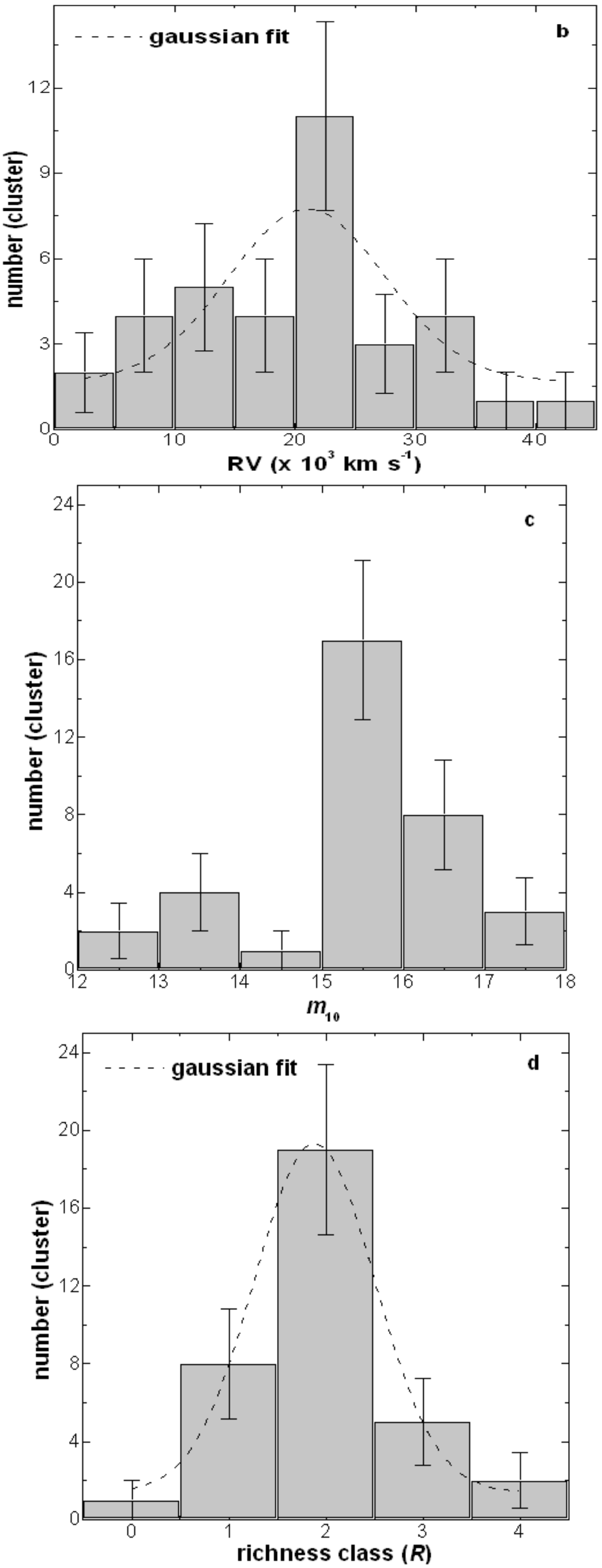


Figure 1: Distribution of 34 Abell clusters in the equatorial coordinate system. The Virgo cluster (x) can be seen.

The NASA/IPAC extragalactic database (NED) was used to check the compilation of galaxy samples in the catalogues. If given, RV and the morphology of the galaxy are noted. The estimation of background galaxies in the cluster region was based on the area distribution of background galaxies around the cluster region. It is estimated that the background contamination of galaxies in the investigated cluster region is ~ 10±5%. These objects include lens of distant galaxies. We removed these galaxies from the database. The foreground field galaxies in the investigated cluster region were identified with the help of the Uppsala General Catalogue of Galaxies (Nilson 1973, 1974), the Third Reference Catalogue of Bright Galaxies (de Vaucouleurs et al. 1991), the ESO/Uppsala Survey of the ESO (B) Atlas (Lauberts 1982), Photometric Atlas of Northern Bright Galaxies (Kodaira et al. 1990) and the Southern Galaxy Catalogue (Corwin et al. 1985). These field galaxies have been removed from the database. A transparent glass with a hairy line was placed along the major diameter of the object. A protector of 15 cm radius was used to measure PA. The errors in the PAs were determined by comparing the measured values with known values in the catalogue (mainly UGC). It turned out to be less than 10 degree. The error in diameters, mainly due to a limited step size, was estimated to be 5 arcsec.





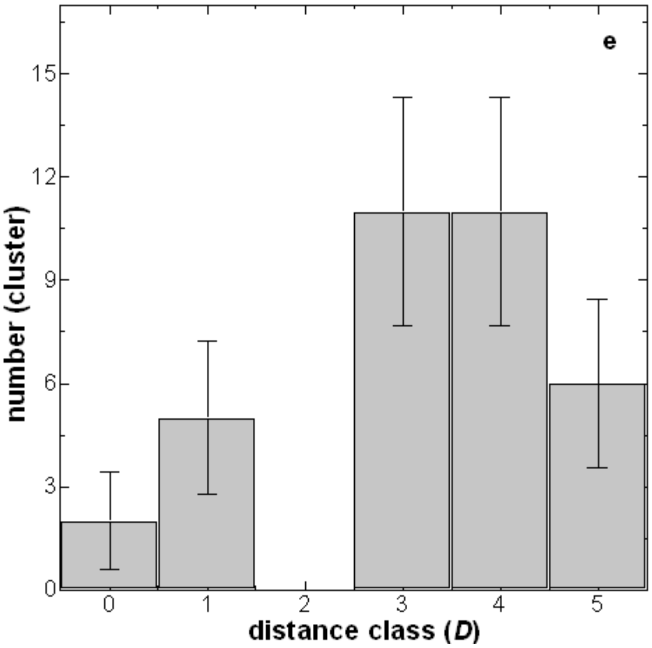


Figure 2: The distribution of BM (Bautz & Morgan 1970) type classification (a), radial velocity RV (b), magnitude of the tenth brightest cluster member (m_{10}) (c), richness class (R) (d), and distance class (d) (e) of the clusters studied. The observed values with statistical ±1σ error bars are shown. The dashed lines (b,d) represent the Gaussian fit.

We have included all types of clusters in our database. Fig. 2 shows the morphology, mean RV, magnitude of the tenth brightest cluster member (m_{10}), richness (R) and distance class (D) distribution of the cluster. Our database contains all types of clusters: regular or symmetrical (BM I), intermediate (BM I-II, II, II-III) and irregular or asymmetrical (BM III) (Fig. 2a). The maximum and minimum RV s of the clusters are ~ 1 000 (Virgo) to ~ 41 000 (A0787) km/s (Fig. 2b). There are 11 clusters that have mean RV 20 000 to 25 000 km/s in our database. Because of this bin, the center of the Gaussian fit is found at 21 000 km/s (Fig. 2b). There are 25 clusters that have m10 value in the range 15 to 17 (Fig. 2c). The center of the Gaussian fit of R distribution is found at ~2 (Fig. 2d). There were 19 clusters that have Abell richness R = 2. There were no clusters that have D = 2 in our database (Fig. 2e). Eleven each clusters are at the distance class D = 3 and 4.

3. METHOD OF ANALYSIS

Astronomical data is often accompanied by several selection effects. One can regard these selection effects as a noise in the database. In such situations, even though all control parameters (independent variables) remain constant, the resultant outcomes (dependent variables) vary. A process of quantitatively estimating the trend of the outcomes, also known as regression or curve fitting, therefore becomes necessary. In this work, we have analyzed the database of ~6,500 galaxies in different context. For this we performed linear and polynomial fits in the position angle (PA) distribution. The slopes of the fitted curves, the center and width of the Gaussian fits, the standard deviation of the fit and the correlation probability (that the correlation coefficient zero) are discussed.

In addition to this, we have carried out three statistical tests, namely, chi-square, auto-correlation and Fourier in order to distinguish anisotropy from isotropy in the PA-distribution. We set the chi-square probability $P(> c^2) = 0.050$ as the critical value to discriminate isotropy from anisotropy. We expect an auto correlation coefficient $C \rightarrow 0$ for an isotropic distribution. For a detailed description of the auto-correlation test see Godlowski (1994).

The Fourier test is useful when the deviation from isotropy is slowly varying with the angles (in our case, PA). In the PA-distribution, Fourier test gives the clue regarding the deviation from isotropy. The Fourier coefficient D_{11} gives the direction of departure from isotropy. The first order Fourier probability function $P(>D_1)$ estimates whether (smaller value of $P(>D_1)$ or not (higher value of $P(>D_1)$ a pronounced preferred orientation occurs in the sample. The positive (negative) D_{11} value at $> 1\sigma$ level suggests that the PAs of the galaxies tend to be oriented perpendicular (parallel) to the equatorial plane.

4. RESULTS: POSITION ANGLE DISTRIBUTION

Figure 3 shows the PA distributions of galaxies in 35 clusters. In the figure, solid circles with statistical $\pm 1\sigma$ error bars represent the observed distribution. The Abell name and the BM classifications are given. The solid and dashed lines represent the expected and best fit curves, respectively.

Here we analyze the distribution of the PAs of galaxies. The conditions for anisotropy are the following: the chi- square probability $P(> c^2) < 0.050$, correlation coefficient $C/\sigma(C) > 1$, first order Fourier coefficient $D_{11}/\sigma(D_{11}) > 1$, and the first order Fourier probability $P(> D_1)<0.150$. The eighth to eleventh columns of Table 1 list these statistical parameters. The last two columns give the standard deviation (PA^{SD}) and the correlation probability (PA^{P}) of the linear fit in the PA-distribution. In the Fourier test, $D_{11}/\sigma(D_{11}) < 1$ (i.e., negative) suggests that the PA of galaxies tend to lie in the equatorial plane. In other words, a negative D_{11} suggests that the rotation axis of galaxies tend to be oriented perpendicular with respect to the equatorial plane. Similarly, $D_{11} > 0$ (i.e., positive) indicates that the rotation axis of galaxies tend to lie in the equatorial plane.

In the histograms, a hump at 90 ± 45^{o} suggests that the PAs of galaxies tend to lie in the equatorial plane. All 9 BM type I clusters show isotropy in chi-square test (Table 1). The chi-square probability $(P(>c^2))$ is found to be > 5% in these clusters. In the Fourier test, the cluster A3560 showed negative D_{11} value at $> 1.5\sigma$ level, suggesting anisotropy (Table 1). In the histogram (Fig. 3g), a hump at 90^{o} can be seen. This hump leads this cluster to show a preferred alignment in the PA-distribution. Thus, the PA of galaxies in the cluster A3560 tends to lie in the equatorial plane.

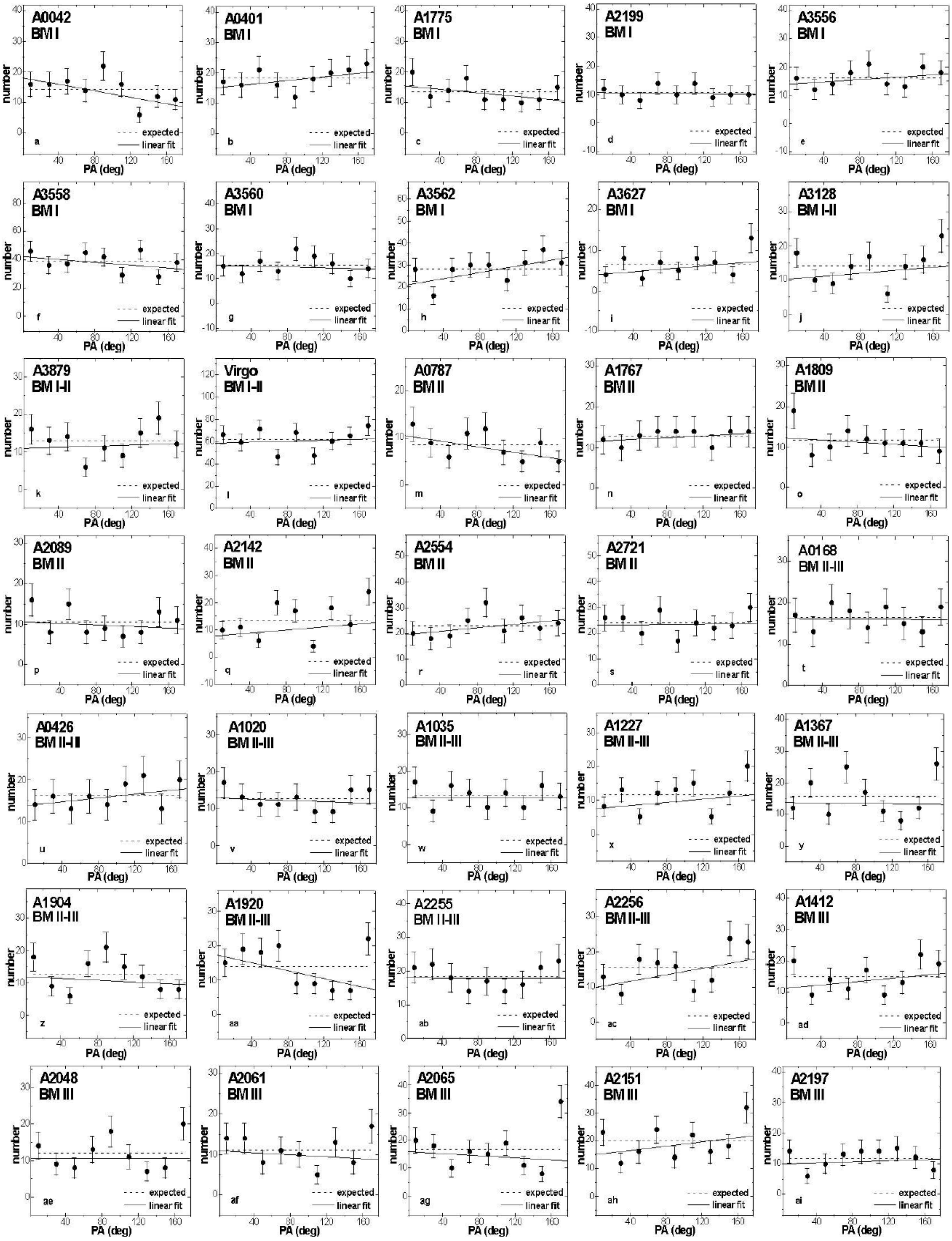


Figure 3: Position angle (PA) distribution of galaxies in 35 clusters. The solid circles with statistical ±1σ error bars represent the observed PA-distribution. The Abell name and the BM type classifications are given. The solid and dashed lines represent the expected and the best fit curves, respectively.

Table 1: Statistics of position angle distribution of galaxies in 35 Abell clusters. The first column lists the Abell number. The BM type morphology and radial velocity (RV) of the cluster are given in the second and third columns. The tenth brightest magnitude of cluster galaxies is given in the fourth column. The distance and richness class as given in ACO catalog (Abell et al. 1989) is listed in fifth and sixth columns. The next column lists the total number of galaxies in the cluster. Eighth-eleventh columns give the chi-square probability ($P(>c^2)$), correlation coefficient ($C/C(\sigma)$), first order Fourier coefficient ($D_{11}/D_{11}(\sigma)$), and first order Fourier probability P ($P(>D_1)$) in the PA-distribution. The last two columns list the standard deviation (PA^{SD}) and the correlation probability (PA^{P}) of the linear fits in the PA-distribution.

Abell	BM	RV (km/s)	m_{10}	D	R	N_T	$P(>c^2)$	$C/C(\sigma)$	$D_{11}/D_{11}(\sigma)$	$P(>D_1)$	PA^{SD}	PA^{P}
0042	I	32,587	17.1	5	3	165	0.197	+0.7	-1.2	0.093	1.2	0.094
0401	I	22,424	15.6	3	2	211	0.755	+0.4	+1.2	0.368	0.8	0.218
1775	I	20,866	15.7	4	2	135	0.510	+0.0	+0.9	0.247	0.8	0.217
2199	I	9,156	13.9	1	2	117	0.914	-0.5	-0.5	0.866	0.7	0.806
3556	I	14,360	16.4	4	2	163	0.755	+0.1	-0.3	0.863	0.8	0.335
3558	I	14,390	15.1	3	4	395	0.255	-1.7	-0.2	0.734	1.2	0.307
3560	I	14,660	15.1	3	3	159	0.532	+0.1	-1.7	0.241	1.0	0.725
3562	I	16,632	15.5	3	2	278	0.282	+0.4	+0.1	0.291	1.1	0.091
3627	I	4,881	14.2	1	1	65	0.184	-1.5	+0.7	0.585	1.1	0.304
3128	I-II	17,958	15.1	3	3	153	0.055	+0.0	+1.9	0.114	1.6	0.588
3879	I-II	20,386	16.1	4	2	119	0.313	+0.3	+1.9	0.101	1.3	0.819
Virg	I-II	1,131	12.5	0	4	556	0.126	-1.7	+1.9	0.165	1.4	0.779
0787	II	40,532	16.9	5	2	98	0.392	+0.0	-0.3	0.574	0.9	0.110
1767	II	21,045	15.7	4	1	158	0.985	+0.0	-0.4	0.913	0.5	0.366
1809	II	23,624	15.8	4	1	128	0.515	-0.6	+0.1	0.961	0.9	0.497
2089	II	21,945	15.8	4	1	111	0.382	-0.7	+1.7	0.198	1.0	0.681
2142	II	26,951	16.0	4	2	149	0.001	-2.4	+0.5	0.578	2.1	0.564
2554	II	31,778	16.9	5	3	252	0.589	+0.2	-1.3	0.269	0.8	0.206
2721	II	34,386	17.0	5	3	274	0.674	-0.9	+1.2	0.488	0.9	0.908
0168	II-III	13,466	15.4	3	2	175	0.886	-0.5	-0.2	0.901	0.7	0.951
0426	II-III	5,486	12.5	0	2	166	0.793	-0.4	+0.0	0.555	0.7	0.250
1020	II-III	19,457	16.0	4	1	149	0.762	+0.3	+1.6	0.252	0.8	0.684
1035	II-III	23,953	15.4	3	2	157	0.729	-1.1	+0.6	0.819	0.9	0.992
1227	II-III	33,577	16.6	5	2	139	0.039	-1.0	+0.5	0.690	1.6	0.492
1367	II-III	6,595	13.5	1	2	166	0.004	-1.3	+0.5	0.264	1.7	0.936
1904	II-III	21,225	15.6	3	2	131	0.028	+1.4	-2.0	0.137	1.5	0.672
1920	II-III	39,273	17.0	5	2	167	0.008	+1.7	+1.5	0.001	1.5	0.167
2255	II-III	24,163	15.3	3	2	229	0.746	+0.7	+2.0	0.124	0.9	0.964
2256	II-III	18,018	15.3	3	2	162	0.038	+1.2	+1.0	0.441	1.4	0.218
1412	III	25,003	15.9	4	2	162	0.128	-0.3	+1.8	0.104	1.3	0.434
2048	III	28,330	16.0	4	1	122	0.073	-0.1	+0.2	0.970	1.3	0.985
2061	III	23,024	15.7	4	1	129	0.254	-0.9	+2.0	0.120	1.3	0.686
2065	III	21,765	15.6	3	2	195	0.000	-2.3	+2.1	0.109	1.8	0.700
2151	III	10,943	13.8	1	2	190	0.047	-1.3	+1.3	0.341	1.3	0.344
2197	III	9,223	13.9	1	1	119	0.582	+0.3	-1.3	0.214	1.1	0.684

The D_{11} value is found to be positive at > 1.5σ level in all three BM type I-II clusters, suggesting similar preferred alignments in the PA-distribution. The humps at 170° (A3128 & Virgo cluster) and at 150° (A3879) can be seen (Fig. 3j,k,l). Thus, the PA of galaxies in the clusters A3128, A3879 and Virgo tend to be oriented perpendicular the equatorial plane. The humps at 70° and 170° lead the cluster A2142 to show a bimodal orientation in the PA-distribution (Fig. 3q). A BM type II cluster (A2089) showed the D_{11} value > 1.5σ, suggesting anisotropy.

We studied PA-distributions of 10 BM types II-III clusters. A mixed result is found here: D_{11} value negative for A1904, positive for A1020, A1920 and A2255. The cluster A1367 showed a bimodal orientation: PA of galaxies tends to be oriented both the parallel (hump at 70°) and the perpendicular (hump at 170°) with respect to the equatorial plane. Three BM type III clusters (A1412, A2161 & A2065) showed anisotropy in the PA-distribution. The D_{11} value is found to be positive at > 1.5σ level (Table 1). These clusters showed similar alignments. The PA of galaxies in these clusters tends to be oriented perpendicular the equatorial plane. The cluster A2048 showed bimodal alignments (Fig. 3ae).

The minimum and maximum values of the standard deviation (PA^{SD} in Table 1) in the linear fits are found to be 0.5 (A1767, D = 4) and 2.1 (A2142, D = 4), respectively. Interestingly, no clusters showed the correlation probability (PA^{P}) < 5%. Thus, the linear fits can be considered as the best fit curve in the PA-distribution.

5. DISCUSSION

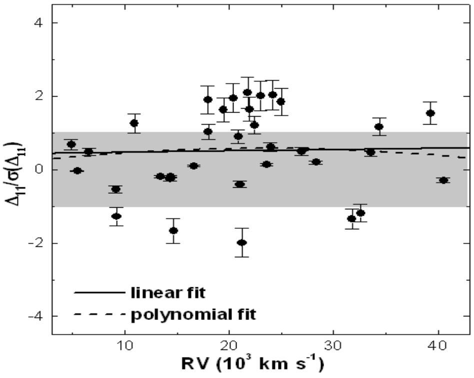


Figure 4: The RV versus orientation parameter ($D_{11}/\sigma(D_{11})$) in the PA distribution of galaxies in 35 Abell cluster. A solid circle with error bars represents a cluster. The solid and dashed lines correspond to the linear and polynomial (second order) fits, respectively. The isotropy and anisotropy is separated by the grey-shaded region: $-1 \leq (D_{11}/\sigma(D_{11})) \leq +1$ for the isotropy and $(D_{11}/\sigma(D_{11})) \geq \pm 1$ for anisotropy.

Here we discuss possible relationship between the mean RV of the cluster and the position angle (PA) of galaxies in the cluster. Fig. 4 shows the scatter plot between the mean RV of the cluster and the orientation parameter ($D_{11}/\sigma(D_{11})$). In the figure, the slope of the linear fit line is approximately null, suggesting no relations between preferred alignments and the mean RV of the cluster. A good agreement between the linear and the second order polynomial fit supports this result. Thus, the preferred alignments of galaxies in the clusters are found to be independent of the mean RV of the cluster.

No relation between the mean RV of the cluster and the orientation parameter ($D_{11}/\sigma(D_{11})$) is noticed in the PA-distribution. The slope of the best fit line is found to be parallel (approximately) to the X-axis, suggesting random alignments (Fig. 4). Thus, the preferred alignments of galaxies in the clusters are found to be independent of the mean RV of the cluster.

6. PREVIOUS WORKS

The PA-distribution of 126 galaxies in Abell 2199 was studied by Thompson (1976). The chi-square probability $P(>c^2)$ was 48% in his calculation suggesting no significant alignment. Our result is similar to that result obtained by Thompson (1976) in the PA-distribution. We found 91% probability in the chi-square test (Table 1). The only cluster in which Thompson (1976) found a significant preference in the PA-distribution was Abell 2197. He analyzed the PA-distribution of 114 galaxies in Abell 2197 and found anisotropy whereas Adams et al. (1980) analysed 58 galaxies of the same cluster and found isotropy. We found isotropy ($P(>c^2)$ = 58%) when analyzing PA-distribution of 106 galaxies in this cluster. So, our results agree with Adams et al. (1980) in the PA-distribution. Thompson (1976) found isotropy when analyzing

PA distribution of 115 galaxies in Abell 2151. Our result does not agree with Thompson's result. We found anisotropy when analyzing PA-distributions of 177 galaxies in this cluster. This disagreement might be due to the rich (50% more) database.

The core of the Shapley Concentration is dynamically very active; the main cluster Abell 3558 appears to be interacting with the other clusters Abell 3562 and Abell 3556 (Bardelli et al. 1994). In our study, the galaxies in the main cluster Abell 3558 show isotropy whereas Abell 3560 shows anisotropy in the Fourier test ($D_{11}/\sigma(D_{11})= +1.7$). In a substructure analysis Bardelli et al. (1998) they discussed the core of the Shapley concentration and suggested that the core complex is the result of a series of incoherent group-group and cluster-group merging.

Oegerle & Hill (2001) performed a dynamical study of 25 clusters containing centrally located cD galaxy. These are BM type I cluster. The shape of the cluster velocity distribution is found Gaussian for A1767 and A1809 whereas non-Gaussian for A2089. Interestingly, we found anisotropy for A2089 and isotropy for A1767 and A1809 in the PA-distribution. Thus, the clusters that have non-Gaussian type velocity distribution show anisotropy in PA-distribution of their galaxies. Oegerle & Hill (1994) studied dynamics of A1809 using redshift data reported by Hill & Oegerle (1993). The cD galaxy of this cluster shows no significant peculiar velocity with respect to the global velocity distribution. We do not notice preferred alignments in this cluster. Hence, this cluster behaves as a late-type cluster (like BM III). Probably, the BM type classification misleads this cluster.

The cluster A2142 is a cooling core cluster containing active radio galaxies in the core (Markovic et al. 2004). The radio sources in this cluster might play an important role in the energetic of the cooling cluster core. We noticed a bimodal orientation in the PA-distribution of galaxies in A2142 cluster: the galactic planes of galaxies tend to orient both the parallel and perpendicular with respect to the equatorial plane. This alignment might have a connection with energetic of the cluster core.

7. CONCLUSION

We measured diameters and the position angles of 5,688 galaxies in POSSII and ESO films using 25-fold magnification microscope. These galaxies belongs to the 34 Abell cluster that have mean RV ~ 1 000 to 43,000 km/s. The distributions of the major diameter, inclination and position angles of galaxies in the clusters are studied. In order to study the nature of the scatter plots in these distributions, we used linear, polynomial (second order) and Gaussian fits. The expected distributions are compared with the fitted curves. In the PA-distribution, the preferred alignments are identified using three statistical tests: chi-square, auto-correlation and the Fourier. Our results are as follows:

(1) The alignments of galaxies in the cluster are found to be independent of the mean RV of the cluster. In few clusters (A3560, A3128, A3879, A2089, A1020, A1904, A2255, A1412, A2061, A2065 and the Virgo)we noticed preferred alignments.

(2) The preferred alignments of galaxies in the cluster and the cluster morphology are found to be independent. As expected, no relation is observed between the cluster morphology and the optical search limit.

Thus, the optical search limit depends upon the mean RV of the cluster whereas the preferred PA is found to be independent of the mean RV of the cluster. In the future, we intend to focus our work on the role of the dark matter in the visible mass distribution mechanism within the cluster.

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REFERENCES

[1] Abell, G.O., Corwin, H.G., Olowin, R.P., 1989. *Astrophys. J. Supp*. **70**:1-170.

[2] Adams, M.T., Strom, K.M., Strom, S.E., 1980. *Astrophys. J.* **238**:445-455.

[3] Argyres, P.C., Groth, E.J., Peebles P.J.E., Struble, M.F., 1986. *Astronom. J.* **91:** 471-783.

[4] Aryal, B., Saurer, W., 2005. *Monthly Notices Royal Astron. Soc.*. **360**: 125-133.

[5] Bardelli, S. et al., 1994. *Monthly Notices Royal Astron. Soc.* **267**:665-674.

[6] Bardelli, S., Pisani, A., Ramella, M., Zucca, E., Zamoreni, G. 1998. *Monthly Notices Royal Astron. Soc.* **300**: 589-598.

[7] Barkanan, R., Loeb, A., 2003. *Nature* **421**: 341-345.

[8] Bautz, L.P., Morgan, W.W., 1970. *Astrophys. J.* **162**: L149-L154.

[9] Binggeli, B., Sandage, A., Tammann, G.A., 1985. *Astronom. J.* **90**: 1681-1690.

[10] Corwin, H.G., de Vaucouleurs, A., de Vaucouleurs, G., 1985. *Univ. Texas Monogr. Astron.* **4**: 1-80.

[11] de Vaucouleurs, G., de Vaucouleurs, A., Corwin et al., 1991. *Third Reference Catalogue of Bright Galaxies*, Springer-Verlag, New York.

[12] Djorgovski, S., 1983. *Astrophys. J.* **274**: L7-L11.

[13] Flin, P., Godlowski, W., 1986. *Monthly Notices Royal Astron. Soc.* **222**: 525-534.

[14] Godlowski, W., 1994. *Monthly Notices Royal Astron. Soc.* **271**: 19-36.

[15] Godwin, J., Metcalfe, N., Peach, J., 1983. *Monthly Notices Royal Astron. Soc.* **202**: 113-127.

[16] Gregory, S., Thompson, L., Tifft W., 1981. *Astrophys. J.* **243**: 411-423.

[17] Haynes, M., Giovanelli, R., 1984. *Astronom. J.* **89**: 6, 758-765.

[18] Hill, J.M., Oegrele, W.R., 1993. *Astronom. J.* **106**: 831-840.

[19] Holmberg, E., 1946. *Medd. Lund. Astron. Obs.*, Ser **VI**: No. 117.

[20] Hu, F.X., Wu, G.X., Su, H.J., Liu, Y.Z.: *Astronom. Astrophys.* **302**, 45 (1995)

[21] Kodaira, K., Okamura, S., Ichikawa, S., 1990. *Photometric Atlas of Northern Bright Galaxies*, Univ. of Tokyo Press, Tokyo.

[22] Lauberts, A., 1982. *ESO/Uppsala Survey of the ESO B Atlas*. ESO, Garching bei Muenchen.

[23] MacGillivray, H.T., Dodd R.J., 1979. *Monthly Notices Royal Astron. Soc.* **186**: 69-78.

[24] MacGillivray, H.T., Dodd R.J., 1979. *Monthly Notices Royal Astron. Soc.* **186**: 743-755.

[25] MacGillivray, H.T., Dodd R.J., 1985. *Astronom. Astrophys.* **145**, 269-278.

[26] Markovic, T., Owen, F.N., Eilek, J.A.: in Reiprich T.H., Kempner J.C., Soker N., eds., 2004. Proc. *The Riddle of Cooling Flows in Galaxies and Clusters of Galaxies* **E28**, Virginia: p.61.

[27] Nilson, P., 1973. *Uppsala General Catalogue of Galaxies*. Nova Acta Uppsala University, Ser. **V**:A, Vol.1.

[28] Nilson, P., 1974. *Upps. Astron. Obs. Rep:* **5**.

[29] Oegrele, W.R., Hill, J.M., 1994. *Astronom. J.* **107**:857-867.

[30] Oegrele, W.R., Hill, J.M., 2001. *Astronom. J.* **122**:2858-2877.

[31] Peebles, P.J.E., 1988. *Astrophys. J.* **332**, 17-28.

[32] Strom, S., Strom, K., 1978. *Astronom. J.* **83**: 732-744.

[33] Thompson, L.A., 1976. *Astrophys. J.* **209**, 22-34.