THE ASTROPHYSICAL JOURNAL, 405:413–418, 1993 March 10

COMPACT GROUPS OF GALAXIES AND LARGE-SCALE STRUCTURE

G. G. C. PALUMBO,[1,2] P. SARACCO,[1] C. MENDES DE OLIVEIRA,[3] P. HICKSON,[3]
V. TORNATORE,[4] AND G. C. BAIESI-PILLASTRINI[1]
Received 1992 March 2; accepted 1992 July 16

ABSTRACT

The relative orientation of a homogeneous sample of 92 compact groups of galaxies taken from Hickson's catalog is investigated. No evidence is found for these groups of galaxies to be aligned with either their nearest neighbors or with Abell clusters. However, a weak indication of alignment is found for groups connected in large structures such as "chains" and/or "filaments." Two concentrations are found: one of 17 groups extends for 93 h^{-1} Mpc, the other of 15 groups for 83 h^{-1} Mpc. Both have an average recession velocity of $\sim$6300 km s^{-1}. The alignment of the groups in the concentrations may be suggestive of a real effect. This result supports the argument that group orientations reflect their origin in chainlike or filamentary protosuperclusters.
Subject headings: galaxies: clustering — large-scale structure of universe

1. INTRODUCTION

As emphasized by West (1989a), alignment studies of groups of galaxies are powerful means for discriminating between different cosmogonic models. Alignment effects among grouped galaxies can be studied using the position angle (P.A.) of each group major axis. West (1989a) has studied orientation of groups of galaxies in a sample taken from the Center for Astrophysics group catalog (Geller & Huchra 1983) and a catalog of groups of galaxies extracted from the Southern Sky Redshift Survey (Maia, da Costa, & Latham 1989). He found that those groups exhibit a tendency to be aligned with their neighbors on scales extending to 15–30 h^{-1} Mpc (the Hubble constant H_0 has been chosen to be 100 km s^{-1} Mpc^{-1} and h is defined as $h = H_0/100$ throughout the paper). This result is predicted in both the dissipative pancake scenario, in which group formation must have occurred after the formation of superclusters (Zel'dovich 1970) and the explosion scenario (Ostriker & Cowie 1981) in which the formation of bubbly structures dominates the topology. In this latter case groups would be aligned on small scales, but not on large scales. In the present paper, the orientation of groups of galaxies of the Hickson Compact Groups Catalog (hereafter HCGs; Hickson 1982) with respect to one another are investigated. These groups form a statistically homogeneous sample which has been well studied at several wavelengths (see Hickson 1990 for a review). This sample has some advantages with respect to that used by West. HCGs are generally thought to be real, physical systems which do not suffer severely from contamination by nonmember galaxies. On the other hand, they do not cover the whole sky as they were selected from the POSS prints; therefore, some differences in behavior found by West between northern and southern groups cannot be tested. In § 2 we describe the sample used. Section 3 describes the group orientations and the alignment analysis. Finally, in § 4, the conclusions are presented.

[1] Dipartimento di Astronomia, Università di Bologna, Via Zamboni 33, 40126 Bologna, Italy (Postal address for G. B. P., G. G. C., & P. S.).

[2] Also Istituto di Tecnologie e Studio delle Radiazione Extraterrestri, Consiglio Nazionale delle Ricerche, Bologna, Italy.

[3] Department of Geophysics and Astronomy, University of British Columbia, 2219 Main Mall, Vancouver, BC, Canada V6T 1W5.

[4] Istituto di Radioastronomia/Consiglio Nazionalle delle Ricerche, Via Irnerio 46, 40126, Bologna, Italy.

2. DATA

The present sample is derived from the homogeneous catalog of 100 compact groups of galaxies described by Hickson (1982, with the revisions of Hickson, Kindl, & Auman 1989). Essentially complete velocity information is now available for the whole sample (Hickson et al. 1992). All galaxies whose velocities differ from the group median velocity by 1000 km s^{-1} or more were assumed to be physically unrelated to the group and were removed from the sample. This revised sample contains 92 compact groups of galaxies, 69 of which contain four or more members.

A major advantage of this sample when compared to other ones, is its relative freedom from contamination by nonmember galaxies (Hickson et al. 1992). Such contamination was a significant problem in previous alignment studies (see West 1989a and references therein).

From accurate galaxy coordinates (x_i, y_i) measured from the POSS prints (Hickson et al. 1989), position angles (θ_i) of the major axes and ellipticities ϵ of the groups were computed. The position angle of the group is taken to be the angle that the major axis makes with the north-south direction, measured north through east. It has been calculated using the formula

$$tg(2\theta) = \frac{2U_{xy}}{U_{xx} - U_{yy}}$$

where $U_{xx,yy,xy}$ are the second moments of the galaxy distribution defined as

$$U_{xx} = \sum_i^n (x_i - \bar{x})^2/n \ , \quad U_{xy} = \sum_i^n (x_i - \bar{x})(y_i - \bar{y})/n \ ,$$

$$U_{yy} = \sum_i^n (y_i - \bar{y})^2/n$$

(Stobie 1980). The ellipticity is defined as $\epsilon = (1 - b/a)$, where a and b are the major and the minor axis of the group respectively.

In order to estimate the uncertainties involved in the determination of the P.A. θ as described above, a sample of 20,000 simulated groups with the same ϵ and galaxy distributions was constructed. The ellipses in which the galaxies of each group were distributed were assumed to have zero P.A. (i.e., major axis coincident with the N-S direction). The distribution of these estimated P.A. is a Gaussian centered on zero. The dispersion around zero indicates how the P.A. calculated approximates the real value. In our case 68% (1 σ) of all P.A. fall within 20° to be compared to 15° found for loose groups and typical uncertainty of 30° usually quoted for clusters of galaxies (West 1989a).

Data for the HCG sample are presented in Table 1. The column headings are as follows: column (1), group catalog number from Hickson (1982); columns (2) and (3), right ascention and declination, respectively (epoch 1950), of the group center (from the positions given in Hickson et al. 1989); column (4), number of galaxies in each group (excluding galaxies with discordant redshifts); column (5), mean redshift from Hickson et al. (1992); column (6), position angle; column (7), ellipticity. Figure 1 shows the distribution of the HCGs on the sky. Different symbols are used to identify the two concentrations found (see later).

3. ANALYSIS

The sample was first checked against bias toward a nonpreferential direction, e.g., the Earth's north pole. Then three different tests were performed to ascertain the presence or absence of anisotropies in the position angle distribution of groups: (1) alignments of the P.A. of each group with that of its nearest neighbor and with the vector joining the group to its nearest neighbor, (2) the orientation of each group was compared with the direction of all neighboring groups included in different ranges of group separation, (3) the orientation of HCGs embedded in large-scale structure was analyzed. Groups with their P.A. were then superposed to the Uppsala General Catalogue of Galaxies (UGC) (Nilson 1973) and, from 00° to −40° in declination to the Morphological Catalog of Galaxies (MCG) (Vorontsov-Vel'yaminov, Krasnogorskaya, & Arkhipova 1962, 1963, 1964, 1968, 1974). This gives an idea of how HCGs are located in respect to the large-scale structure.

TABLE 1

Complete Revised Sample of Hickson's Compact Groups

HCG	α	δ	Number of Galaxies	z	P.A.	ϵ	HCG	α	δ	Number of Galaxies	z	P.A.	ϵ
1......	0 23 24.41	25 26 46.7	4	0.0339	88	0.878	53......	11 26 18.96	21 02 13.9	3	0.0206	34	0.982
2......	0 28 48.97	08 10 19.3	3	0.0144	27	0.826	54......	11 26 38.24	20 51 38.4	4	0.0049	125	0.888
3......	0 31 43.55	−07 51 52.1	3	0.0255	76	0.412	55......	11 29 7.75	71 05 22.8	4	0.0526	172	0.927
4......	0 31 45.36	−21 43 12.9	3	0.0280	6	0.833	56......	11 29 53.51	53 13 16.5	5	0.0270	90	0.646
5......	0 36 18.98	06 47 20.8	3	0.0410	27	0.834	57......	11 35 13.79	22 16 02.1	7	0.0304	25	0.665
6......	0 36 38.57	−08 40 22.0	4	0.0379	104	0.851	58......	11 39 32.94	10 35 36.8	5	0.0207	39	0.404
7......	0 36 47.51	00 36 26.2	4	0.0141	69	0.470	59......	11 45 53.12	12 59 51.3	4	0.0135	87	0.492
8......	0 46 55.78	23 18 33.2	4	0.0545	11	0.523	60......	12 0 32.21	51 57 42.1	4	0.0625	60	0.789
10......	1 23 22.47	34 27 05.2	4	0.0161	83	0.589	61......	12 9 53.49	29 26 37.8	3	0.0130	64	0.513
12......	1 25 2.38	−04 55 38.5	5	0.0485	121	0.454	62......	12 50 30.61	−08 56 36.9	4	0.0137	179	0.669
13......	1 29 52.29	−08 07 59.4	5	0.0411	151	0.368	63......	12 59 23.35	−32 30 28.7	3	0.0311	117	0.541
14......	1 57 20.66	−07 18 02.9	3	0.0177	15	0.946	64......	13 23 8.09	−03 35 45.0	3	0.0360	42	0.970
15......	2 5 2.95	01 54 58.0	6	0.0228	128	0.479	65......	13 27 5.39	−29 14 37.7	5	0.0475	151	0.759
16......	2 7 4.39	−10 23 09.0	4	0.0132	64	0.770	66......	13 36 47.14	57 33 45.5	4	0.0699	120	0.805
17......	2 11 22.83	13 04 49.6	5	0.0604	53	0.619	67......	13 46 30.75	−06 58 01.6	4	0.0245	61	0.626
20......	2 41 19.48	25 53 40.6	5	0.0484	104	0.513	68......	13 51 29.15	40 33 26.9	5	0.0080	63	0.422
21......	2 42 56.35	−17 53 45.6	3	0.0251	79	0.790	69......	13 53 12.58	25 18 44.0	4	0.0294	38	0.624
22......	3 1 9.40	−15 49 40.2	3	0.0090	126	0.483	70......	14 1 54.07	33 34 13.7	4	0.0636	118	0.999
23......	3 4 39.31	−09 47 12.6	4	0.0161	64	0.313	71......	14 8 45.02	25 44 04.1	3	0.0301	22	0.233
24......	3 17 53.97	−11 02 37.1	5	0.0305	88	0.769	72......	14 45 36.94	19 16 02.6	4	0.0421	23	0.942
25......	3 18 10.56	01 14 25.6	4	0.0212	5	0.608	73......	15 0 26.96	23 33 14.4	3	0.0449	84	0.747
26......	3 19 33.44	−13 49 50.9	7	0.0316	91	0.339	74......	15 17 12.89	21 04 31.9	5	0.0399	62	0.345
27......	4 16 58.61	−11 49 28.7	4	0.0874	97	0.998	75......	15 19 19.70	21 21 45.3	6	0.0416	70	0.793
28......	4 24 56.40	−10 25 39.7	3	0.0380	16	0.735	76......	15 29 14.96	07 29 20.1	7	0.0340	46	0.435
29......	4 32 48.99	−30 38 43.0	3	0.1047	88	0.801	79......	15 56 59.93	20 53 51.0	4	0.0145	180	0.633
30......	4 33 56.60	−02 56 09.1	4	0.0154	55	0.453	80......	15 58 46.61	65 22 04.6	4	0.0310	76	0.508
31......	4 59 8.43	−04 19 55.2	3	0.0137	112	0.793	81......	16 15 54.25	12 54 57.6	4	0.0499	11	0.671
32......	4 59 28.99	−15 29 54.8	4	0.0408	31	0.635	82......	16 26 28.03	32 56 21.0	4	0.0362	143	0.642
33......	5 7 53.69	17 57 51.0	4	0.0260	113	0.714	83......	16 33 12.91	06 22 09.6	5	0.0531	111	0.337
34......	5 19 6.72	06 38 05.7	4	0.0307	55	0.895	84......	16 46 40.66	77 55 59.6	5	0.0556	37	0.776
35......	8 41 56.87	44 42 16.4	6	0.0542	2	0.793	85......	18 51 31.25	73 17 21.0	4	0.0393	90	0.410
37......	9 10 35.78	30 12 58.0	5	0.0223	19	0.578	86......	19 48 50.27	−30 57 19.5	4	0.0199	74	0.184
38......	9 24 58.06	12 29 58.4	3	0.0292	116	0.981	87......	20 45 20.74	−20 01 52.4	3	0.0296	178	0.358
39......	9 26 55.47	−01 07 38.5	4	0.0701	37	0.869	88......	20 49 47.15	−05 56 45.4	4	0.0201	133	0.832
40......	9 36 24.10	−04 37 39.0	5	0.0223	172	0.584	89......	21 17 32.39	−04 07 24.9	4	0.0297	109	0.882
42......	9 57 55.80	−19 24 28.1	4	0.0133	72	0.540	90......	21 59 10.51	−32 11 56.1	4	0.0088	8	0.886
43......	10 8 39.70	00 11 32.7	5	0.0330	154	0.385	91......	22 6 21.25	−28 01 36.6	4	0.0238	157	0.845
44......	10 15 13.99	22 04 19.0	4	0.0046	141	0.598	92......	22 33 40.37	33 42 12.6	4	0.0215	128	0.843
45......	10 15 46.72	59 21 27.8	3	0.0732	163	0.748	93......	23 12 48.29	18 43 59.6	4	0.0168	133	0.592
46......	10 19 29.69	18 06 39.5	4	0.0270	138	0.871	94......	23 14 46.96	18 27 03.4	7	0.0417	145	0.824
47......	10 23 7.57	13 59 28.2	4	0.0317	168	0.805	95......	23 16 58.92	09 13 34.3	4	0.0396	84	0.363
48......	10 35 24.47	−26 49 18.9	3	0.0094	21	0.908	96......	23 25 28.19	08 29 55.4	4	0.0292	71	0.685
49......	10 53 19.24	67 26 54.2	4	0.0332	116	0.796	97......	23 44 50.71	−02 35 26.4	5	0.0218	65	0.278
50......	11 14 14.85	55 11 33.4	5	0.1392	77	0.499	98......	23 51 38.33	00 05 37.9	3	0.0266	30	0.840
51......	11 19 43.45	24 34 33.2	5	0.0258	79	0.784	99......	23 58 9.85	28 06 26.9	5	0.0290	153	0.320
52......	11 23 40.59	21 21 39.5	3	0.0430	9	0.857	100......	23 58 46.14	12 50 39.0	3	0.0178	55	0.735

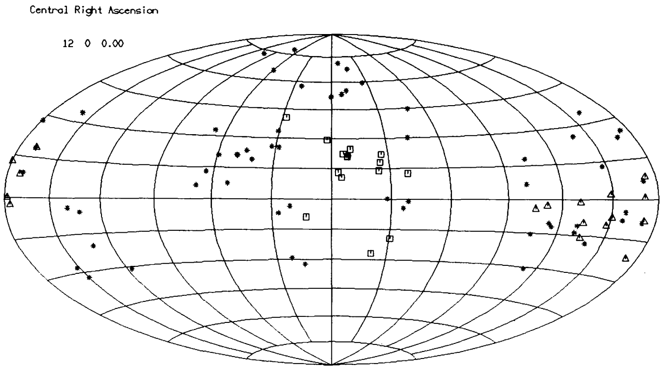

FIG. 1.—Spatial distribution of HCG. Concentrations A (open triangles [△]) and B (open squares [□]); see text.

3.1. *Distribution of HCG Position Angles Relative to Earth's Pole*

In order to test whether the P.A. of HCGs suffer from significant systematic errors we examined, following Struble & Peebles (1985), the fundamental and first harmonic ($n = 1$ and 2) of the Fourier transform of the position angle distribution relative to a non preferential direction, e.g., Earth's pole:

$$C_n = \sqrt{\frac{2}{N}} \sum_1^N \cos (2n\theta_i) ,$$

$$S_n = \sqrt{\frac{2}{N}} \sum_1^N \sin (2n\theta_i) ,$$

where N is the number of groups in the sample and θ_i is the P.A. If the position angles are isotropically distributed between 0° and 180°, the dimensionless deviations C_n and S_n are normally distributed with zero mean and unit variance when $N \gg 1$. Table 2 shows the Fourier coefficients (col. [1]) for our sample (col. [2]) and two subsamples selected by the criterion of increasing group ellipticity (i.e., including groups with ϵ larger than 0.5 (col. [3]) and smaller than 0.5 (col. [4]), respectively). All are consistent with isotropy.

3.2. *Orientations of HCGs Relative to Their Nearest Neighbor*

In order to test whether the orientations of neighboring groups show a tendency to be parallel among themselves, correlations of ψ (the acute angle between the position angle of a group and that of its nearest neighbor), and ϕ (the acute angle between the position angle of the group and the great circle joining its center to that of its nearest neighbor as described in Binggeli [1982] and Struble & Peebles [1985] for clusters of galaxies) were searched for. Note that the nearest neighbor of a group may have a different group as its nearest neighbor. Following again Struble & Peebles (1985), we constructed the statistical estimator (standardized variable)

$$\Delta_\delta = \frac{\sqrt{12N}}{90} \left\{ \sum_1^N \frac{\delta_i}{N} - 45 \right\} ,$$

where δ_i is the angle (ψ or ϕ) studied, in degrees. This estimator reveals any preferred value of δ_i with respect to an isotropic distribution. The values of $\Delta_\psi = -0.33$ and $\Delta_\phi = 0.03$ obtained for ψ and ϕ have a chance occurrence probability of 74% and 98%, respectively. These probabilities were estimated by two independent methods: one by generating a random distribution of angles, the other analytically calculating the normal distribution function for the Δ_δ. Both methods gave the same probabilities whose values are given above. This shows no indication of alignment and is consistent with isotropy at small scales. In order to minimize the uncertainties due to P.A. determination, two subsamples of HCGs have been extracted. The first one includes the 69 groups formed by four or more galaxies. The second one again the 69 groups (but not the same) with ellipticities $\epsilon \geq 0.5$. In Table 3 the values of the calculated Δ_ψ, Δ_ϕ are given. No evidence for alignment is present.

Next following Binggeli (1982) for each HCG the spatially closest neighbor in the sample was determined. In Figure 2 the angle ϕ between the group P.A. defined by the direction to the

TABLE 2

FOURIER TRANSFORM COEFFICIENTS FOR DISTRIBUTION OF HCG POSITION ANGLES

Coefficient	All	$\epsilon > 0.5$	$\epsilon < 0.5$
C_1	−0.08	1.16	−2.17
S_1	0.96	0.65	0.81
C_2	0.78	1.04	−0.25
S_2	−0.13	0.94	−1.90

TABLE 3

VALUES OF STATISTICAL ESTIMATORS Δ_δ FOR RELATIVE ACUTE ANGLES ψ AND ϕ FOR SUBSAMPLE OF HCGs WITH FOUR OR MORE GALAXIES[a] AND HCGs WITH ELLIPTICITY ϵ GREATER THAN 0.5

Subsample	Δ_ψ	$P(\Delta_\psi)$	Δ_ϕ	$P(\Delta_\phi)$
$N \geq 4$	−0.74	46	−0.23	82
$\epsilon \geq 05$	−0.70	49	−0.67	50

[a] ($N \geq 4$).

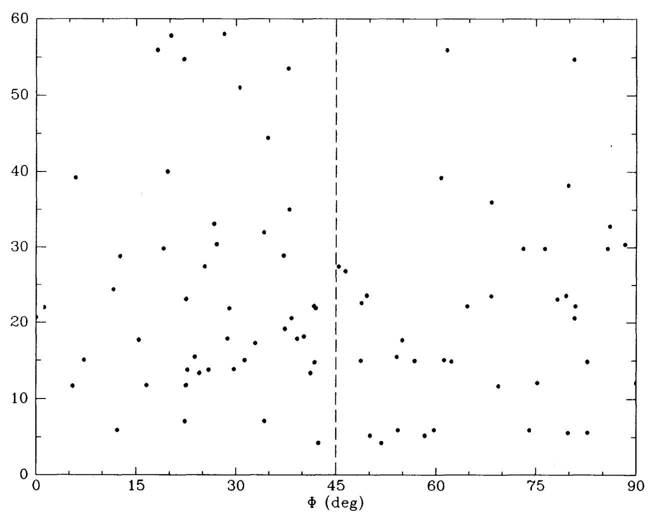

FIG. 2.—Differences ϕ between the group P.A. and the P.A. defined by the direction to the closest neighboring group vs. the spatial distance D to the closest neighbor. For clusters Binggeli (1982) found that if the distance to the closest neighbor was smaller than 30 Mpc, the position angle difference was smaller than 45°: a cluster tends to "point" to its closest neighbor if the distance between them is sufficiently small. No such effect is apparent for HCGs.

closest neighbor versus the spatial distance D (in Mpc) to the closest neighbor is plotted. The striking effect found by Binggeli for clusters here is not present.

3.3. *Orientation of HCGs Relative to Their Neighbors*

In order to compare West's result with those obtained from our sample, we searched for any tendency neighboring groups may show in being aligned with one another. Different separation intervals were considered and Δ_ϕ (as defined in the previous section) calculated. The subsets contain only those groups included in different ranges of group separation D as selected by West (1989a). Table 4A provides the numerical values found: column (1), west separation intervals in megaparsecs; column (2), number of angles considered; column (3), Δ_ϕ; column (4), probability of chance occurrence. As can be seen, there is no evidence for alignment. The same test has been applied to the two subsamples defined in § 3.2. The results are summarized in Tables 4B and 4C.

TABLE 4A

VALUES OF STATISTICAL ESTIMATOR Δ_δ FOR RELATIVE ACUTE ANGLE ϕ FOR WHOLE SAMPLE OF HICKSON COMPACT GROUPS

D(Mpc)	Angles	Δ_ϕ	$P(\Delta_\phi)$
0–10	6	0.22	83
10–20	32	0.54	59
20–30	70	−0.17	86
30–40	103	0.16	87
40–50	153	−0.82	41
50–60	180	−0.55	58
0–30	108	0.21	83
30–60	436	−0.76	44

TABLE 4B

VALUES OF STATISTICAL ESTIMATOR Δ_δ FOR RELATIVE ACUTE ANGLE ϕ FOR SUBSAMPLE OF GROUPS WITH FOUR OR MORE GALAXIES

D(Mpc)	Angles	Δ_ϕ	$P(\Delta_\phi)$
0–10	3	1.22	24
10–20	12	−0.59	56
20–30	31	1.17	24
30–40	50	0.52	61
40–50	73	−1.32	19
50–60	99	−0.50	62
0–30	46	0.97	34
30–60	222	−0.85	40

TABLE 4C

VALUES OF STATISTICAL ESTIMATOR Δ_δ FOR RELATIVE ACUTE ANGLE ϕ FOR SUBSAMPLE OF GROUPS WITH ELLIPTICITIES $\epsilon \geq 0.5$

D(Mpc)	Angles	Δ_ϕ	$P(\Delta_\phi)$
0–10	1	0.26	85
10–20	13	0.83	41
20–30	31	−0.43	67
30–40	54	1.62	10
40–50	75	−0.05	96
50–60	105	−1.02	31
0–30	45	0.13	90
30–60	234	0.06	95

3.4. *Orientations of HCGs Embedded in Large-Scale Structures*

The 92 HCGs have been plotted in Figure 3 with their P.A. superposed to the UGC and MCG catalogs of galaxies to show how they are placed and oriented in respect to the large-scale structure of galaxies in a comparable redshift interval. West (1989b) has demonstrated a tendency for clusters to align with the superclusters in which they reside. Along this line we looked for those HCGs belonging to well-known superclusters. Only a small subset in the Coma-A1367 supercluster has been found. Therefore, in order to verify the alignments of clustered groups in large structures, a catalog of clustered HCGs has been constructed using percolation analysis which is the most appropriate algorithm for finding systems like concentrations or filaments. In summary the following procedure was adopted: given N points in a volume V one defines the average distance $\bar{l}$, between points, as the following quantity

$$\bar{l} = (V/N)^{1/3} .$$

For each point one selects which other points fall within a sphere of radius $r = B_c \bar{l}$ centered on the first point considered. The points found are "friends" of the initial center point. Repeating the procedure one identifies "friends of friends." The process reaches an end when all N points have been used as centers of spheres. For the 92 HCGs considered, the volume $V \sim 1.8 \times 10^8\ h^{-3}$ Mpc^3 provides $\bar{l} \sim 125\ h^{-1}$ Mpc. In order to verify whether for HCGs some alignments are present in the interval 15–30 h^{-1} Mpc as found by West (1989a) for loose groups, r was varied within this interval. The assumption was made that structures, if any, had to contain five or more groups. Starting from 15 h^{-1} Mpc the first positive answer was found at $r \sim 18\ h^{-1}$ Mpc where a concentration of 10 groups emerged. However, alignment tests give $\Delta_\psi = 1.02$ and $\Delta_\phi = -1.40$ with 33% and 18% chance probability, respectively. Increasing r to 20 h^{-1} Mpc increases the concentration content of one group only while the number of pairs and triplets increases considerably. For $r \sim 22\ h^{-1}$ Mpc two concentrations were found: concentration A contains 17 HCGs and concentration B 15, respectively. Table 5 contains, in the upper panel for concentration A and in the lower panel for concentration B, the following information: column (1), HCG number; columns (2) and (3), right ascention and declination of the groups, respectively (epoch 1950); column (4), number of galaxies in the groups; column (5), heliocentric radial velocities of the groups in km s^{-1}, column (6), groups P.A.; column (7), ellipticity ϵ. As for the whole HCG sample, the groups in both concentrations, with their associated P.A., have been superposed to the UGC and MCG catalogs (Fig. 4*a*, concentration

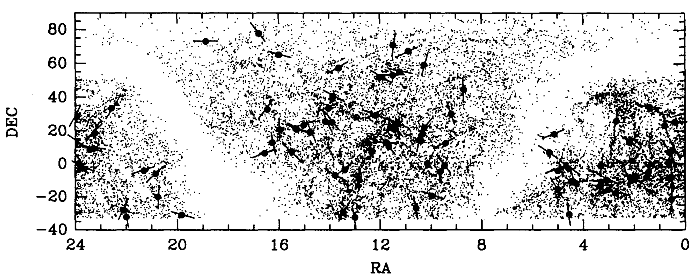

FIG. 3.—The 92 HCGs are plotted, with their P.A., superposed to the UGC catalog extended southward with the MCG catalog. The overall impression is that there is no systematic correlation between group orientation and galaxy structures.

TABLE 5

PARAMETERS FOR HCGS BELONGING TO CONCENTRATIONS A AND B

HCG	α	δ	Galaxy	v(km s^{-1})	P.A.	ϵ
			Concentration A			
2......	0 28 48.97	8 10 19.3	3	4317	27°	0.826
7......	0 36 47.51	0 36 26.2	4	4227	69	0.470
16......	2 7 4.39	−10 23 9.0	4	3957	64	0.770
93......	23 12 48.29	18 43 59.6	4	5037	133	0.592
100......	23 58 46.14	12 50 39.0	3	5336	55	0.735
14......	1 57 20.66	−7 18 2.9	3	5306	15	0.946
15......	2 5 2.95	1 54 58.0	6	6835	128	0.479
23......	3 4 39.31	−9 47 12.6	4	4827	64	0.313
25......	3 18 10.56	−1 14 25.6	4	6356	174	0.997
22......	3 1 9.40	−15 49 40.2	3	2698	126	0.483
30......	4 33 56.60	−2 56 9.1	4	4617	55	0.453
31......	4 59 8.43	−4 19 55.2	3	4107	112	0.793
97......	23 44 50.71	−2 35 26.4	5	6536	65	0.278
3......	0 31 43.55	−7 51 52.1	3	7645	3	0.997
98......	23 51 38.33	0 5 37.9	3	7975	30	0.840
96......	23 25 28.19	8 29 55.4	4	8754	71	0.685
4......	0 31 45.36	−21 43 12.9	3	8394	0	1.000
			Concentration B			
38......	9 24 58.06	12 29 58.4	3	8754	116°	0.981
46......	10 19 29.69	18 6 39.5	4	8094	138	0.871
47......	10 23 7.57	13 59 28.2	4	9503	168	0.805
51......	11 19 43.45	24 34 33.2	5	7735	65	1.000
53......	11 26 18.96	21 2 13.9	3	6176	34	0.982
57......	11 35 13.79	22 16 2.1	7	9114	25	0.665
58......	11 39 32.94	10 35 36.8	5	6206	39	0.404
59......	11 45 53.12	12 59 51.3	4	4047	87	0.492
61......	12 9 53.49	29 26 37.8	3	3897	70	1.000
62......	12 50 30.61	−8 56 36.9	4	4107	179	0.669
68......	13 51 29.15	40 33 26.9	5	2398	63	0.422
44......	10 15 13.99	22 4 19.0	4	1379	141	0.598
54......	11 26 38.24	20 51 38.4	4	1469	125	0.888
48......	10 35 24.47	−26 49 18.9	3	2818	10	1.000
42......	9 57 55.80	−19 24 28.1	4	3987	72	0.540

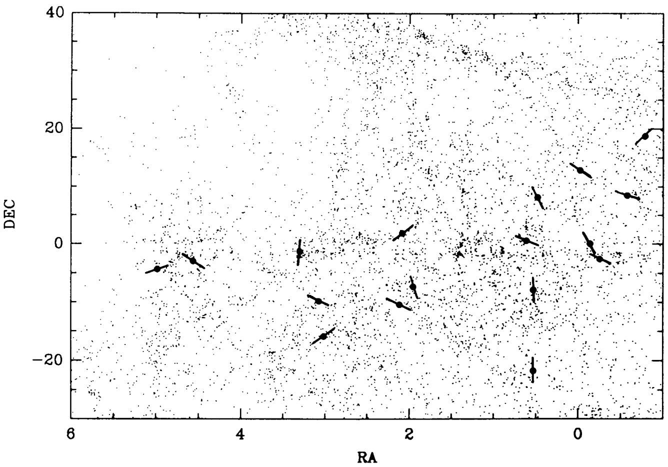

FIG. 4*a*

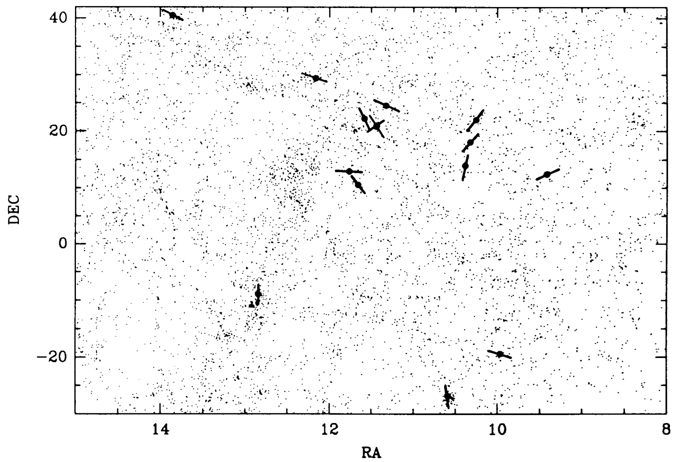

FIG. 4*b*

FIG. 4.—(*a*) As in Fig. 3 but only for those groups found to belong to concentration A (see text). (*b*) As for (*a*), but for concentration B.

A; Fig. 4*b*, concentration B). Figures 5*a* and 5*b* show the corresponding cone diagrams. The alignment tests previously performed on the complete HCG sample were performed on the groups contained in the two concentrations. The values of Δ_ψ and Δ_ϕ for angles ψ and ϕ referring to HCG in both concentrations A and B are given in Table 6: column (1), Δ_ψ; column (2), probability of chance occurrence; column (3), Δ_ϕ; column (4), probability of chance occurrence; row 1, concentration A; row 2, concentration B. Both group concentrations appear to have some degree of alignment of P.A., as seen by the low probability of chance alignment listed in column (4) for concentration A and columns (2) and (4) for concentration B. For values of r larger than 22 h^{-1} Mpc the estimated chance probabilities for Δ_ψ and Δ_ϕ were always much larger than for concentrations A and B. The tendency of alignment for neighboring groups in both concentrations was also tested as it was previously done for the whole sample. A table analogous to Table 3 was produced but no indication of alignment found. There have been reports in the literature about orientation of brighter galaxies in clusters with the parent cluster (Rhee & Katgert 1987), excess galaxy counts in the direction of the major axis of the brightest galaxies in rich clusters (Argyres, Groth, & Peebles 1986), and alignments of brightest cluster galaxies with large-scale structures (Lambas, Groth, & Peebles 1988a, b; Muriel & Lambas 1989). The findings about concentrations of HCGs support these results. A convincing demonstration that loose groups of galaxies trace the large-scale structures was provided by Ramella, Geller, & Huchra (1989) using the Center for Astrophysics complete redshift survey. It seems that, to some extent, HCGs also follow the same structures.

Hickson Compact Groups could be oriented toward structure much larger than the neighboring structure of galaxies. In order to test this hypothesis the procedure adopted in §§ 3.2 and 3.3 above was repeated for the 92 HCGs and the 568 Abell clusters of galaxies (Corwin & Olowin 1988) for which an average redshift is available. As in the previous cases, the results were negative as can be seen from Table 7 in which the values of Δ_ϕ and related chance alignment probabilities for

TABLE 6

VALUES OF STATISTICAL ESTIMATOR Δ_δ FOR RELATIVE ACUTE ANGLE ψ AND ϕ FOR HCG BELONGING TO CONCENTRATIONS A AND B

Concentration	Δ_ψ	$P(\Delta_\psi)$	Δ_ϕ	$P(\Delta_\phi)$
A..............	0.25	80	−1.34	18
B..............	−1.62	10	−1.06	29

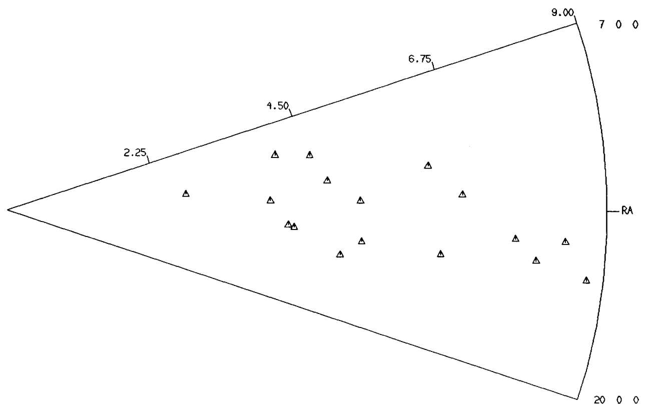

FIG. 5*a*

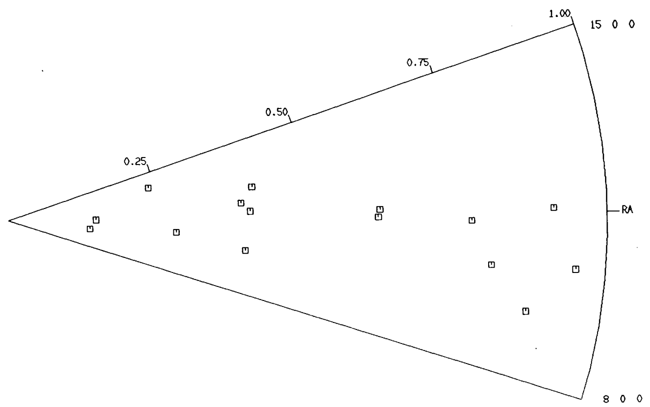

FIG. 5*b*

FIG. 5.—(*a*) Wedge diagram for concentration A. (*b*) as (*a*), but for concentration B.

clusters located in different distance intervals are given. The value of $\Delta_\phi = -1.38$ was found for the nearest cluster with a chance alignment probability of 18%.

4. DISCUSSION AND CONCLUSIONS

From the analysis of the relative orientations of compact groups of galaxies belonging to Hickson's sample the following results were found:

1. No departure from isotropy has been detected among orientations of each group with respect to its nearest neighbor. This uniformity of distribution in space seems to rule out the hypothesis that tidal distortion effects may preferentially align P.A.

TABLE 7

VALUES OF STATISTICAL ESTIMATOR Δ_δ FOR ACUTE ANGLE ϕ BETWEEN HCGs AND ABELL CLUSTERS FOR DIFFERENT SEPARATION INTERVALS

D(Mpc)	Angle	Δ_ϕ	$P(\Delta_\phi)$
0–10............	20	−1.420	16
10–20............	38	−0.207	83
20–30............	97	−0.779	44
30–40............	149	−0.756	45
40–50............	241	0.092	93
50–60............	270	0.277	79

2. There is no evidence that neighboring groups tend to point toward each other. The lack of evidence for alignment may be, at least in part, due to the considerable uncertainties in determining P.A. Such uncertainty is, however, unavoidable since HCGs contain only a few galaxies.

3. No alignment was found between HCGs and Abell clusters.

4. Two concentrations have been constructed using percolation analysis: concentration A, containing 17 HCGs at an average recession velocity of 6256 km s^{-1} and B, containing 15 HCGs at an average recession velocity of 6460 km s^{-1}, centered at $01^h30^m35^s$, $-00°22'23''$ and $11^h40^m08^s$, $11°34'43''$, respectively. The dimensions of the concentrations, i.e., the maximum separation between groups within any concentration, are 93 h^{-1} Mpc for concentration A and 83 h^{-1} Mpc for concentration B, respectively. The results of alignment tests performed on these groups in both concentrations, are suggestive of an alignment effect although they are not statistically significant.

From the above results it is apparent that the HCG sample should be extended, possibly to the whole sky, before one can draw sound statistical conclusions about theory of group formation.

Two of us (G. G. C. P. and P. H.) acknowledge financial support from the North Atlantic Treat Organization. P. H. is also supported by the Natural Sciences and Engineering Research Council of Canada and G. G. C. P. by the Ministero dell'Università e della Ricerca Scientifica of Italy. V. T. was supported by a fellowship of the Italian Consiglio Nazionale delle Ricerche while this work was done. Plots of galaxy catalogs was done with the help of DIRA. We wish to thank M. West who refereed the paper and made many useful suggestions.

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