Orientation of the galaxy groups in the Local Supercluster

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The paper discusses the problem of the orientation of galaxies in groups in the Local Super-cluster (LSC). The existence of the preferred orientation of galaxy group is shown. We found that the orientation of galaxy groups in the Local Supercluster in the scale till about 20 Mpc is strongly correlated with the distribution of neighbouring groups. The line joining the two brightest galaxies is in alignment with both the group major axes and the direction toward the centre of the LSC, i.e. Virgo cluster. These correlations suggest that two brightest galaxies were formed in filaments of matter directed towards the proto supercluster centre. Afterwards, the hierarchical clustering leads to aggregation of galaxies around these two galaxies. The groups are formed on the same or similarly oriented filaments. This picture is in agreement with the predictions of numerical simulations.

1 Introduction

Starting from Binggeli paper, several authors studied the orientation of galaxy groups and clusters. On the basis of optical and X-ray data they found that structures exhibit a tendency to be orientated toward their neighbours. The interpretation of this effect has changed in the last thirty years, but the main idea that this should reflect conditions during the structure formation is still very popular. Numerical simulations gave a better understanding of physical processes leading to structure formation. These simulations were performed in the framework of the cold dark matter (CDM) model, presently regarded as the correct description of the large scale structure formation.

Several numerical simulations, using different approaches and codes, led to the conclusion that the preferred orientation of galaxy clusters in the CDM model is a natural consequence of processes leading to structure formation due to gravitational interaction along filamentary structures. In order to confirm, or deny, this scheme of structure origin we carry out an analysis of the Local Supercluster (LSC) galaxy groups alignment. Groups were taken from the Catalogue of Nearby Galaxies. We selected structures having at least 10 members. There are 61 such groups.

2 Observational data and analysis

It was assumed that groups are two axial ellipsoids. The shape of each group has been determined considering only the projected position of galaxies on the celestial sphere in the supegalactic
coordinate system L, B and applying the covariance ellipse method. This procedure gives the position angle of the group major axis.

The position angle of each group $PA_g$ is calculated counterclockwise from the great circle passing through the position of the cluster centre on the celestial sphere and the northern pole of the LSC. It was assumed that the location of a group centre corresponds to the mean of L and B coordinates of member galaxies and the mean of radial velocity, as given in the Catalogue. Using standard formulae from spherical trigonometry, we calculated the directions between the centre of each group and the centres of the remaining groups. Each direction is a part of the great circle joining the centres of two groups. For each group we calculated the acute angle $\phi$ between the position angle of the major axis of a given group $PA_g$ and direction towards other groups. We also investigated the alignment of the brightest group galaxies and the parent group. We determined the position of the line joining two brightest galaxies in the group $PA_l$ and checked the orientation of this line relative to the position angle of the parent group $PA_g$, the position angle of the brightest galaxy $PA_{bm}$ and the direction towards Virgo cluster $PA_V$.

We checked for isotropy all discussed distributions of position angles $PA_g$, $PA_l$, $PA_{bm}$, $PA_V$ having range $0^\circ - 180^\circ$, as well as differences between position angles $PA_g - PA_V$, $PA_l - PA_V$, $PA_g - PA_l$, $PA_{bm} - PA_g$, $PA_{bm} - PA_l$, $PA_{bm} - PA_V$ being the acute angles (fig.1). It was done using the Kolmogorov - Smirnov test and the $\chi^2$ test. Additionally, we carried out the analysis of these angles for 35 galaxy groups having at least 20 members.

3 Results

The distribution of position angles of the brightest galaxies ($PA_{bm}$) is isotropic as is observed in galaxy structures not containing cD galaxy, which is the case of LSC. The distributions of group position angles $PA_g$ and the line joining two brightest galaxies $PA_l$ are anisotropic at confidence level 95% In the case of the $\chi^2$ test the $PA_l$ is anisotropic only when 35 richer
The distribution of the acute angle $\phi$ between the position angle of the major axis of a given group ($PA_g$) and direction towards other groups. From top to bottom the distributions for groups with $D \leq 10\text{Mpc}$, $10 < D \leq 20\text{Mpc}$, $10 < D \leq 20\text{Mpc}$ and $D > 20\text{Mpc}$ are presented respectively. The dashed lines denote the isotropic distribution.

groups are analysed. The distribution of direction toward Virgo centre $PA_V$ is anisotropic at the confidence level 95%. The strong excess of position angles $PA_g$ is observed in the bin $80^\circ - 100^\circ$, which corresponds to the location of the supergalactic equator. In this bin, the excess of position angles of the structures is $5\sigma$, while the excess of the position line joining two brightest galaxies $PA_l$ is $2.5\sigma$ (for 35 galaxy groups only), when compared to the number expected in a random distribution.

The $\chi^2$ test shows that the difference between the group position angle $PA_g$ and direction towards Virgo cluster $PA_V$ is not random at the confidence level 99% or 95% in the case of richer and poorer groups respectively. For 41 clusters the differences $PA_g - PA_V$ are less than $45^\circ$, while only for 20 clusters they are greater than $45^\circ$. The distribution of the difference $PA_V - PA_l$ is anisotropic only for richer groups. The difference of angles $PA_g - PA_l$ is strongly anisotropic at the confidence level 99%. The observed excess is below $45^\circ$.

The structures have the tendency to point each other only in the case when the distance between groups is smaller than $20\text{Mpc}$ ($H_0 = 75\text{km s}^{-1}\text{Mpc}^{-1}, q_0 = 1/2$ fig.2). We obtain the anisotropy for the differences between the position angle $PA_g$ and direction towards other groups. This effect is at the level of $7\sigma$ for $D \leq 10\text{Mpc}$ and at $2.5\sigma$ for $10 < D \leq 20\text{Mpc}$. For the sample of 35 richer galaxy groups, we also obtained similar effect, but at $2.5\sigma$ level and only for $D \leq 10\text{Mpc}$. A similar tendency, but at $2.3\sigma$ level is observed for the difference between the line joining two brightest galaxies ($PA_l$) and direction towards other groups. Moreover, anisotropies are noted only in the coordinate system connected with the LSC and they are absent in the equatorial coordinate system, which gives further evidences that the orientation is connected with the LSC itself.
4 Conclusions

From the presented analysis of the orientation of galaxy groups in the Local Supercluster the following picture of the structure formation appears. The two brightest galaxies were formed first. They originated in the filamentary structure directed towards the centre of the protocluster. This is the place where the Virgo cluster centre is located now.

Due to gravitational clustering, the groups are formed in such a manner that galaxies follow the line determined by the two brightest objects. Therefore, the alignment of structure position angle and line joining two brightest galaxies is observed. The other groups are forming on the same or nearby filament. The flatness of the LSC additionally contributes to the observed alignment of galaxy groups. The majority of the groups lie close to us. From the selection effect in the catalogue the lack of groups further than the Virgo Cluster centres is observed.

This picture is in agreement with predictions of several CDM models, in which structure formation is due to hierarchical clustering. Moreover, the formation is occurring on the filamentary structure.

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References

1. Binggeli, B. 1982, A&A, 107, 338
2. Struble, M. F., Peebles, P. J. E. 1985, AJ, 90, 542
3. Rhee, G. F. R. N, Katgert, P. 1987, A&A, 183, 217
4. Flin, P. 1987, MNRAS, 228, 941
5. West, M.J. 1989, ApJ, 344, 535
6. Palumbo, G. G. C., Saracco, P., Mendes de Oliveira, C., Hickson, P., Tornatore, V., Baiesi-Pillastrini, G. C. 1993, ApJ, 405, 413
7. Plionis, M. 1994, ApJS, 95, 401
8. Fuller, T., West, M.J., Bridges, T., J. 1999, ApJ, 519, 22
9. Chambers, S.C., Melott, A.L., Miller, C.J. 2002, ApJ, 565, 849
10. Hashimoto, Y., Henry, J.P., Boehringer, H. 2008, MNRAS, 390, 1562
11. Onuora, L.I., Thomas, P.A. 2000, MNRAS, 319, 614
12. Faltenbacher, A., Gottloeber, S., Kerscher, M., Mueller, V. 2002, A&A, 395, 1
13. Faltenbacher, A., Allgood, B., Gottloeber, S., Yepes, G., Hoffman, Y. 2005, MNRAS, 362, 1099
14. Springel, V., et al., 2005, Nature, 435, 629
15. Hopkins, P.F., Bahcall, N.A., Bode, P. 2005, A&A, 618, 1
16. Baslakos, S., Plionis, M., Yepes, G., Gottloeber, S., Turchaninov, V. 2006, MNRAS, 365, 539
17. Hahn., O., Porciani, C., Carollo, C.M., Dekel, A. 2007, MNRAS, 375, 489
18. Hahn., O., Carollo, C.M., Porciani, C., Dekel, A. 2007, MNRAS, 381, 41
19. Aragon-Calvo, M.A., van de Weygaert, R., Jones, B. J. T., van der Hulst, J. M. 2007, ApJ, 655, L5
20. van de Weygaert, R., Bond, J. R. 2008, in: A Pan-Chromatic View of Clusters of Galaxies and the Large - Scale Structures, eds. Plionis, M., Lopez-Cruz, O., Hughes D., Springer, Dordrecht, 335
21. van de Weygaert, R., Bond, J. R. 2008, ibidem 409
22. Tully, R.B. 1988, Nearby Galaxy Catalog, Cambridge Univ.Press, Cambridge