The results of analysis of Rich Galaxy Clusters from CfA2 Redshift Survey spatial distribution

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Abstract. Preliminary results of the investigation of the properties of 7 galaxy cluster from CfA2 redshift survey are discussed in the presented article. Clusters 933, 142, 1046, and 1652 have several peculiarities of the spatial distributions of galaxies. The distributions on absolute magnitude and luminosity represent two areas for clusters 933, 88, 142, 1046, 1101. The investigation of the spatial distribution and other characteristics of 88, 1101, 1046, 142, 933, 1242 and 1652 galaxy clusters allow concluding gravitational lensing effect. Galaxies from these areas are paired accordingly its spectral characteristics and position. Redshifts of these clusters are in the region 0.002 – 0.022. Preliminary results of analysis allow us concluding compact objects or dark matter blobs as lenses. Moreover, groups #933, #142, #1046 and #1652 reveals high-energy $\gamma$-associations on Fermi/LAT 10-Year Point Source Catalog 4FGL-DR2 (4FGL J1144.9 + 1937, 4FGL J0152.2 + 3714, 4FGL J1230.8 + 1223 and 4FGL J1653.8 + 3945); and sources 4FGL J0123.1+3421, 4FGL J1259.5+2332, 4FGL J1353.2+3740 are located inside sizes of clusters #88, #1101 and #1242. Also several anomalies of spatial dynamic of galaxies in these clusters were separated. Joint observations of such clusters by orbital gamma-ray observatories with high angular resolution and ground-based Cherenkov air-shower experiments could possibly clarify the type of gravitational lensing and processes of particle acceleration in these objects especially highest energy of emitted gammas. Thus we propose including these and similar clusters in the programs of observations of the planned experiment GAMMA-400 (Gamma Astronomical Multifunctional Modular Apparatus) with angular resolution $\sim$0.01° at $E_\gamma$ = 100 GeV. Also now it is discussed coordination of multimwavelenth observations program of Cherenkov Telescope Array (CTA) and GAMMA-400 objects list for observations. Moreover, common observations of such clusters by orbital gamma-ray telescopes with high angular resolution and ground-based Cherenkov air-shower experiments could possibly clarify the type of gravitational lenses.

1. Introduction
Clusters of galaxies reveal an independent approach to the problems related to the distribution of matter in our Universe \cite{1}. Galaxy clusters, which are the biggest gravitationally bound systems in the Metagalaxy, have been used to constrain cosmological models and to understand formation of galaxies connecting dark matter halos (DMH) \cite{2, 3}. The differences of galaxies were identified by their luminosity, morphology, and color allowed to study the relation between the topology and properties
of galaxies at the large-scale structure (LSS) and concluding both cosmological parameters and galaxy formation mechanisms on non-linear or quasi-linear scales. Topology analysis was used to test the Gaussian field of the primordial quantum fluctuations (CMB), which are still in the linear regime and maintain their initial topology at large scales while it deviated from the Gaussian form of the topology of the observed galaxy distribution at small scales [4].

Moreover, the investigation of galaxies clusters also relates to the dependence of the characteristics of galaxies on the surrounding medium properties, and the LSS formation in the Metagalaxy. Thus the cluster system kinematics investigation also should estimate possible DM presence due to analysis of several catalogues – for instance, the National Geographic Society Palomar Observatory Sky Survey (Abell catalog of rich clusters of galaxies), Sloan Digital Sky Survey (SDSS) and CfA2 Redshift Survey, [1, 4, 5]. Therefore, the large-scale distribution of matter in the Metagalaxy will be described by analyzing quantities of galaxies to various limiting magnitudes and the redshift surveys [1].

2. The results of second CfA2 redshift survey analysis.

The second CfA redshift survey (CfA2) [5] was started by J. Huchra and M. Geller between 1985 and 1995 due measurements of relative distances via redshifts for about 18000 bright galaxies in the northern sky. It contains data of 1971 galaxies groups (totally 6787 members) that lies at galactic latitudes $b \geq 20^\circ$. The results of analysis of the spatial distributions of galaxies in groups 88, 1101, 1046, 142, 933, 1242 and 1652 are presented at figures 1-3 and table 1. Several peculiarities were presence for group #88 and #1101, for example, at least two parts of galaxy cluster #88 and #1101 could be separated on angular velocities and absolute magnitude, $M_{88} \approx 19.05 \pm 0.05$ and $M_{1101} \approx 20.15 \pm 0.05$ (see figure 4). In addition, the galaxies from these areas are paired accordingly its spectral characteristics and position – see also figures 1 and 4. Then we have analyzed the difference of the angular velocity of five clusters of galaxies according to various distances to the center of clusters – see table 2 and figure 3(b), which shows the asymmetry of motions of galaxies in groups #142, #88, #1101.

Galaxy redshifts of galaxies in clusters 88, 1101, 1046, 142, 933, 1242 and 1652 are in the region 0.002 – 0.032. The investigation of its spatial distribution and other characteristics presented at figures 1-3, reveal gravitational lensing effect. But now objects which are gravitational lenses for these clusters are unknown, we can only concluding as lenses compact objects or dark matter blobs.

We have analyzed Fermi/LAT 10-Year Point Source Catalog 4FGL DR2 [6] and found high energy gamma-emission (HEGE) associations for clusters 933, 142, 1046 and 1652 (4FGL J1144.9+1937, 4FGL J0152.2+3714, 4FGL J1230.8+1223 and 4FGL J1653.8+3945). These active sources are 3C 264, B20149+37, M87 and MRC 501. Furthermore, jet extends up to some hundreds of parsecs with rapidly evolving knot structures observed in 3C 264 ($z=0.021718$) in radio band associated with kiloparsec-scale internal shock collision, but no major activity has been observed around the time of the VERITAS observations [7, 8].

Angular size of such clusters is about 1-2 degree.

Figure 1. The spatial distribution of galaxies in group # 88(a), #1101(b) & #1046 (c).
Table 1. Mean parameters of 7 groups from CfA2

| #  | Number of members | RQF – Relative quantities false (%) | Heliocentric velocity (km/s) | Mean distance of member of group from its center (Mpc) |
|----|------------------|-------------------------------------|-----------------------------|-------------------------------------------------------|
| 1046 | 337              | 2.328                               | 1847 ± 519                  | 1.423                                                 |
| 1101 | 118              | 0.784                               | 7433 ± 751                  | 1.006                                                 |
| 88   | 92               | 1.426                               | 5040 ± 440                  | 1.357                                                 |
| 933  | 63               | 0.372                               | 6656 ± 703                  | 0.497                                                 |
| 142  | 63               | 0.721                               | 4868 ± 496                  | 0.667                                                 |
| 1242 | 26               | 0.406                               | 2750 ± 190                  | 0.384                                                 |
| 1652 | 28               | 1.561                               | 9324 ± 427                  | 1.394                                                 |

Table 2. Difference between angular velocity at various distances of 5 groups

| Distance, Mpc | #1046     | #1101     | #88        | #933       | #142       |
|---------------|-----------|-----------|------------|------------|------------|
| 0.25          | 8.192×10^{-20} | 2.529×10^{-17} | 3.583×10^{-19} | 1.557×10^{-20} |
| 0.5           | 8.269×10^{-20} | 1.810×10^{-17} | 7.807×10^{-18} | 1.369×10^{-19} | 1.088×10^{-19} |
| 0.75          | 6.785×10^{-20} | 8.188×10^{-18} | 1.633×10^{-18} | 8.220×10^{-20} | 4.651×10^{-20} |
| 1             | 4.901×10^{-20} | 8.926×10^{-18} | 6.510×10^{-18} | 8.220×10^{-20} | 1.235×10^{-20} |
| 1.25          | 5.018×10^{-20} | 7.454×10^{-19} | 4.746×10^{-18} |             |             |
| 1.5           | 4.017×10^{-20} | 2.251×10^{-18} | 3.932×10^{-18} |             |             |
| 1.75          | 3.025×10^{-20} | 9.582×10^{-19} | 2.895×10^{-18} |             |             |
| 2             | 2.478×10^{-20} | 1.116×10^{-18} | 1.139×10^{-18} |             |             |
| 2.5           | 1.717×10^{-20} | 1.665×10^{-18} |             |             |             |
| 3             | 6.825×10^{-21}  |             |             |             |             |

Figure 2. The spatial distribution of galaxies in group #142 (a), 933 (b) & 1242 (c).

Figure 3. The spatial distribution of galaxies in group # 1652(a), difference between angular velocity at various distances of 5 groups (b).
Figure 4. Distributions on angular velocity and absolute magnitude for groups 88 (a) and 1101 (b).

Sources 4FGL J0123.1+3421, 4FGL J1259.5+2332, 4FGL J1353.2+3740 are not associated with groups centers but located inside sizes of clusters #88, #1101 and #1242. Common observations of such clusters by ground-based Cherenkov air-shower experiments (for example, Cherenkov Telescope Array (CTA) [9]) and orbital gamma observatories (for instance, planned experiment GAMMA-400 with angular resolution ~0.01° at $E_\gamma = 100$ GeV [10, 11]) possibly clarify the type of gravitational lenses and processes of particles acceleration in these objects especially up to very high energies.

3. Conclusion
The shape of distribution on angular velocity and absolute magnitude shows at least two galaxy populations for groups #1101 and #88 – 105 from 118 and 50 from 88 galaxies are more bright correspondingly separated by $M_{1101} \sim 20.15 \pm 0.05$ and $M_{88} \sim 19.05 \pm 0.05$. The investigation of spatial distributions of clusters 933, 88, 142, 1046, 1101 allow to suppose GL effect but now with unknown objects which are gravitational lenses in these cases. Moreover, clusters #933, #142, #1046 and #1652 reveal high energy gamma emission from active sources, which are associated on Fermi/LAT data and sources 4FGL J0123.1+3421, 4FGL J1259.5+2332, 4FGL J1353.2+3740 are located inside sizes of clusters #88, #1101 and #1242. Common observations of such groups of galaxies by ground-based Cherenkov air-shower experiments and orbital gamma-ray observatories with high angular resolution could possibly clarify the type of gravitational lenses and processes of particles acceleration in these objects especially highest energy of emitted gammas. Thus, studying of high-energy $\gamma$-emission of active galaxies, and entirely anomalous spatial dynamics of galaxies in groups allows research such inhomogeneities and understanding of its nature perhaps caused by dark matter.

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