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 clusters of galaxies from CfA2 redshift survey are discussed in the presented poster. Clusters 933, 142, 1046, 1652 from CfA2 redshift survey and found several anomalies of spatial dynamic of galaxies in these clusters. Moreover, , these objects have high-energy gamma associations on Fermi/LAT data have high energy gamma associations on Fermi/LAT data (4FGL J1144.9+1937 4FGL J0152.2+3714, 4FGL J1230.8+1223 and 4FGL J1653.8+3945). The investigation of the spatial distribution and other characteristics of 933, 1242, 88, 142, 1046 and 1101 galaxy clusters shows gravitational lensing effect. Investigation of high-energy gamma-emission of galaxies and peculiarities of its motion in groups allows studying properties of such inhomogeneities and understanding of its nature possibly caused by dark matter. 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.

Galaxy clustering has been used to constrain cosmological models and to understand formation of galaxies connecting dark matter halos and luminous galaxies. Galaxies are classified by their luminosity, morphology, and color to study the relation between the topology and properties of galaxies tracing the large-scale structure, [1]. Cluster of galaxies, which can be detected from observational data in optical, X-ray (ROSAT All-Sky Survey), and millimeter bands, are the biggest gravitationally bound systems in the Metagalaxy, [2,3]. Thanks to topology analysis, physicists can do the constraining both cosmological parameters and galaxy formation mechanisms on non-linear or quasi-linear scales [1]. Therefore, a large-scale distribution of matter in the Metagalaxy will be generally described by analyzing quantities of galaxies.

The presence of Dark Matter (DM) are proved by some natural evidences such as rotation curves, hot gas in clusters, primordial nucleosynthesis, gravitational lensing. Gravitational lensing is not only a tremendous interesting phenomenon in cosmology and astrophysics but also another evidence for the DM at the galactic cluster scale. The strong gravitational lensing is a powerful tool to determine the masses of galactic cluster cores while the weak lensing is applied to estimate the mass distribution of galaxy clusters [4, 5]. Moreover, investigation on cluster galaxies also relates to problems such as the dependence of the properties of galaxies on the properties of the surrounding medium, and the large- scale structure of the Metagalaxy – see, for example, [6,7].

Preliminary results of investigation of several groups of galaxies characteristics are discussed in the presented article. These studied objects were identified on the basis of the CfA2 redshift survey. Catalog CfA2 contains data of 1971 groups of galaxies which n ≥ 2 members that have redshifts of 1000-15000 km/s and lies at galactic latitudes b ≥ 20° [6].

Redshifts of 1242, 1652, 88, 1101,933, 1046, 142, cluster's members are in the region 0.002 – 0.032. The spatial distributions of its galaxies presented at figures 1-7 The investigation of spatial distribution and other characteristics of 933, 88, 142, 1046, 1101 galaxy clusters shows gravitational lensing effect. The distributions on groups members position, absolute magnitude and luminosity represent two areas for these clusters. Galaxies from these areas are paired accordingly its spectral characteristics and position.

We have analyzed 4FGL Fermi/LAT catalogue [8] and found high energy gamma 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 sources are active galaxies 3C 264, B2 0149+37, M87 and MRC 501. Furthermore, radiogalaxy 3C 264 observed in energy band E> 1 TeV on TeVCat data [9].

We suppose including these and analogues clusters in the programs of observations of planned experiment GAMMA-400 with angular resolution ~0.01° at **Eγ** = 100 GeV and upper energy band ~10 TeV – see, for example, [10,11]. Also now it is discussed coordination of multiwavelength observations program of Cherenkov Telescope Array (CTA) [12] and GAMMA-400 objects list for observations.

Tab.1. Mean parameters of 5 groups from CfA2

#	Quantity of galaxies	RQF, %	Heliocentric velocity (km/s)	Mean distance of galaxies 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

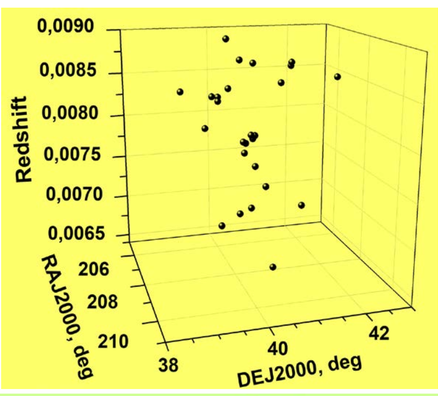

Fig1. The spatial distribution of galaxies in group 1242

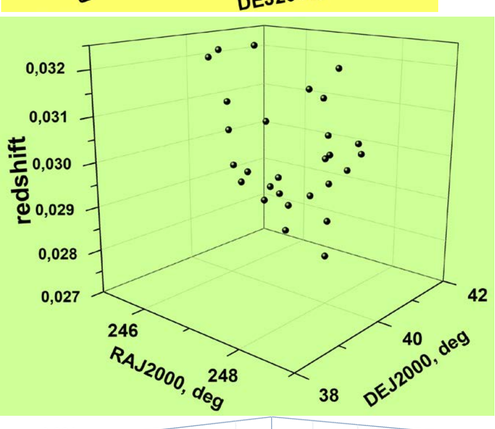

Fig.2. The spatial distribution of galaxies in group 1652

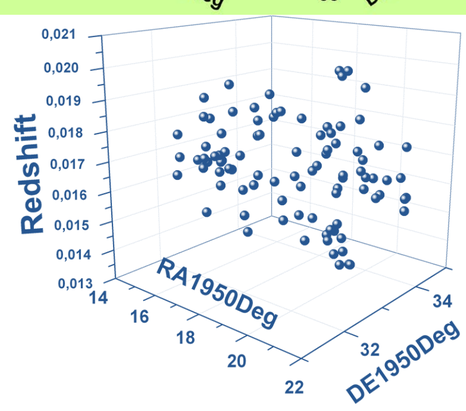

Fig.3. The spatial distribution of galaxies in group 88

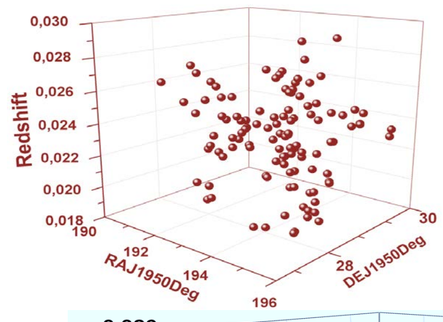

Fig.4. The spatial distribution of galaxies in group 1101

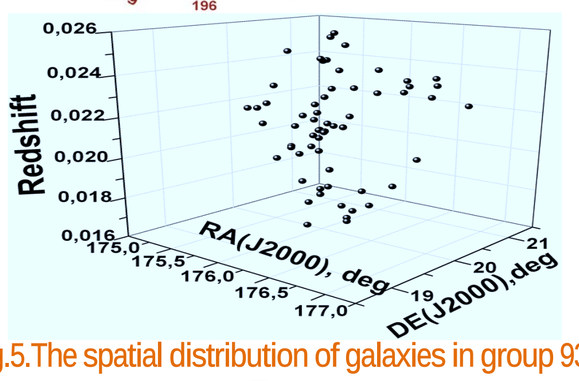

Fig.5.The spatial distribution of galaxies in group 933

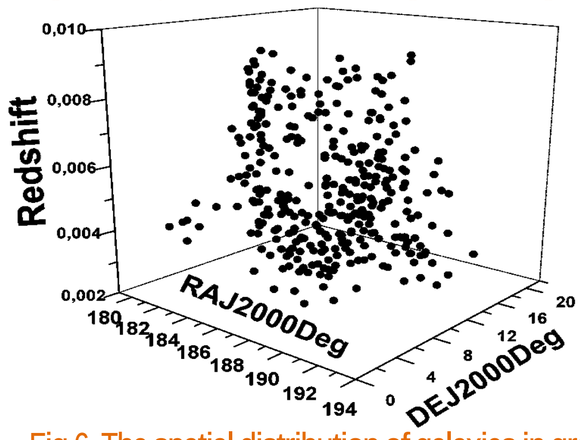

Fig.6. The spatial distribution of galaxies in group 1046

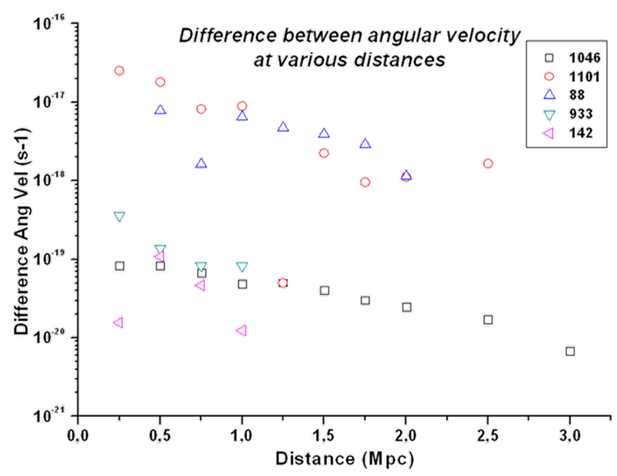

Fig.8. Difference between angular velocity at various distances of 5 groups

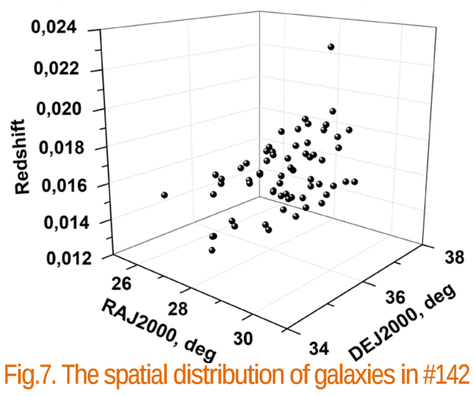

Fig.7. The spatial distribution of galaxies in #142

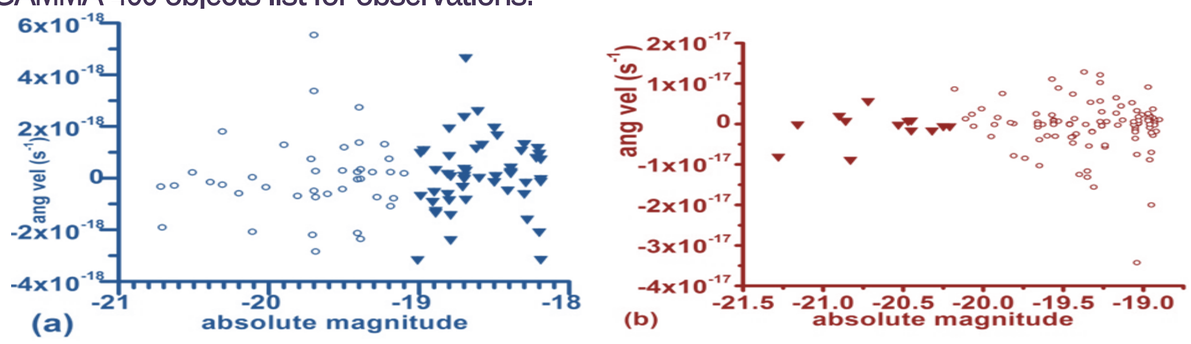

Fig.9. Distributions on angular velocity and absolute magnitude for #1101 (a) and #88 (b)

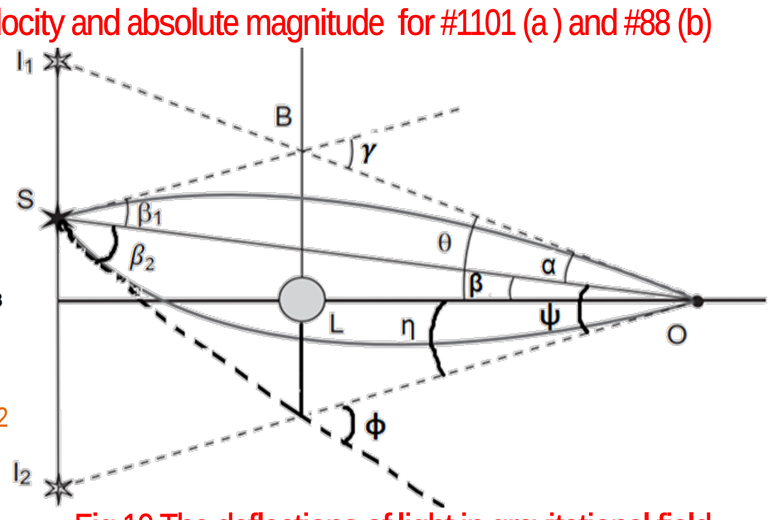

Fig.10.The deflections of light in gravitational field of lens L

The First Image I_1

1. $\beta = \theta - \alpha(\theta)$
2. $\sin\alpha \sim \tan\alpha \sim \alpha$. Thus, $\alpha\, r_S = \gamma r_{LS}$
3. The angular diameter distances: $\gamma = \frac{4GM}{c^2.\xi} = \frac{4GM}{c^2.D_L\,\theta}$
4. The observer-source distance $D_S = \frac{r_S}{(1+z_S)}$ or $D_S = r_S/(1+z_S)$
5. Observer-lens distance $D_L = \frac{r_L}{(1+z_L)}$
6. Lens-source distance $D_{LS} = \frac{r_{LS}}{(1+z_{LS})}$ or $D_{LS} = r_{LS}/(1+z_{LS})$
7. $\beta = \theta - \frac{D_{LS}}{D_S}\gamma$ or $\beta = \theta - \gamma\left(\frac{D_{LS}}{D_S}\right)$ where r is the proper distance in the lens plane
8. The impact parameter $\xi = D_L\theta$
9. Angle of declination: $\alpha(\theta) = \gamma\frac{D_{LS}}{D_S}$, where $\alpha(\theta) = \frac{D_{LS}}{D_S}\frac{4GM}{c^2.D_L\,\theta} = \frac{4GM}{c^2}\frac{D_{LS}}{D_S D_L}\frac{1}{\theta} = \frac{\theta_E^2}{\theta}$
10. The Einstein radius: $\theta_E = \sqrt{\frac{4GM}{c^2}\frac{D_{LS}}{D_S D_L}} \sim$ $\sim 3''\left(\frac{M}{10^{12}M_\odot}\right)^{1/2}\left[\frac{D_{LS}/(D_S D_L)}{1/Gpc}\right]^{1/2}$
11. The lens equation for a point-mass lens is: $\beta = \theta - \frac{\theta_E^2}{\theta}$,

Where $\theta_\pm = \frac{1}{2}\left(\beta \pm \sqrt{\beta^2 + 4\,\theta_E^2}\right) =$ $= \frac{\theta_E}{2}(u \pm \sqrt{u^2+4})$

Where $u = \frac{\beta}{\theta_E}$ is the (actual) source position in units of θ_E

The second Image I_2

12. $\alpha D_L = \beta_1 D_{LS}$
13. $\gamma = \alpha + \beta_1$
14. $\phi = \frac{4GM}{c^2.\zeta} = \frac{4GM}{c^2.D_L\eta}$
15. $\psi = \eta - \phi\frac{D_{LS}}{D_S} \leftrightarrow \eta + \beta = \eta - \phi\frac{D_{LS}}{D_S}$ $\leftrightarrow \beta = -\phi\frac{D_{LS}}{D_S}$
16. $\omega(\eta) = \phi\frac{D_{LS}}{D_S} = \frac{D_{LS}}{D_S}\frac{4GM}{c^2.D_L\eta} =$ $= \frac{4GM}{c^2}\frac{D_{LS}}{D_S D_L}\frac{1}{\eta} = \frac{\theta_E^2}{\eta}$
17. $\psi = \eta + \beta = \eta + \theta - \frac{\theta_E^2}{\theta}$ $\rightarrow \eta_\pm = \frac{1}{2}\left(\psi - \eta \pm \sqrt{(\psi-\eta)^2 + 4\,\theta_E^2}\right)$
18. $\psi D_L = \beta_2 D_{LS} \leftrightarrow (\eta + \beta)D_L = \beta_2 D_{LS}$
19. The magnification μ is equal to the ratio of angular areas: $\mu = \left|\frac{\theta d\theta}{\beta d\beta}\right|$, where θ/β is the tangential magnification (perpendicular to the O-L-S plane) and dθ/dβ is the radial magnification (in the O-L-S plane, perpendicular to the line of sight).

The relevant distances are r_L (observer-lens), r_{LS} (lens-source), and r_S (observer-source).

More than 1000 groups of galaxies were analyzed and seven ones were selected taking to account the amount of members in group (it should be more than 50) – see table 1. The results of analysis is presented at figures 1-7. At least two galaxies populations for group of #1101 and #88 could be separated - see also figure 9. The resolve of this system for mentioned in table1 groups will be in the next step.

Conclusions.

Preliminary analysis results allow to conclude following:

1. 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 M1101~20.15±0.05 and M88~19.05±0.05
2. Preliminary results assume concluding the presence of several peculiarities on analyzed these spatial distributions for seven groups.
3. Clusters 933, 142, 1046 and 1652 have high-energy gamma emission from active sources, which are associated on Fermi/LAT data. Included, the radiogalaxy 3C 264 was caught in the very high energy band E> 1 TeV. Common observations of such clusters by orbital gamma-ray observatories with high angular resolution and ground-based Cherenkov air-shower experiments. Therefore, investigation of high-energy gamma-emission of active galaxies, and entirely anomalous spatial dynamics of galaxies in groups allows studying such inhomogeneities and understanding of its nature possibly caused by dark matter.
4. Several characteristics of clusters of galaxies 933, 88, 142, 1046, 1101 from CfA2 Redshift survey allow suppose gravitational lensing effect. The resolve of this system for mentioned in table1 groups will be in the next step.

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