Preliminary results of rich galaxy clusters’ spatial distribution analysis on CfA2 Redshift Survey data: Compact objects or dark matter presence at redshift less 0.032

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Preliminary results of the investigation of the properties of 13 clusters of galaxies from CfA2 redshift survey are discussed in the presented article. The distributions on absolute magnitude and luminosity represent two areas for clusters #88, 1101, 1046, 142, 933, 1242, 1652, 107, 150, 316, 317, 961, 977. Redshifts of these clusters are in the region 0.002 – 0.032. 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. Also several anomalies of spatial dynamic of galaxies in these clusters were separated. Such structure could be caused by dark matter presence inside cluster in configuration similar to Zeldovich pancake or gravitational lensing on compact object or dark matter blob located between galaxy cluster and observer. Several peculiarities have found on the spatial distributions of galaxies in clusters #933, 142, 1046, and 1652. Moreover, these groups reveals association with high-energy gamma-emission sources on Fermi/LAT 10-Year Point Source Catalog 4FGL DR2 data (4FGLJ1144.9+1937, 4FGLJ0152.2+3714, 4FGLJ1230.8+1223 and 4FGLJ1653.8+3945 correspondingly). These sources are active galaxies 3C 264, B2 0149+37, M87 and MRC 501. Furthermore, 3C 264 and M87 observed in subTeV energy band by VERITAS data. 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 $\sim 0.01^\circ$ at $E_\gamma = 100$ GeV and several TeV upper energy band. Also now it is discussed coordination of multiwavelength observations program of Cherenkov Telescope Array (CTA) and GAMMA-400 objects list for observations.

Keywords: Clusters of galaxies; CfA2 redshift survey.
1. Introduction

Galaxy clusters are the biggest gravitationally bound systems\textsuperscript{1, 2} reveal an independent approach to the problems related to the distribution of matter at various redshift ranges – particulars given in Ref. 4 and Ref. 5. It possible to use the results of its characteristics investigation to understand processes of formation of such systems and galaxies contained its possibly connecting dark matter halos (DMH) and to constrain cosmological models – see, for example Ref. 6 and Ref. 5. The differences of galaxies were identified by their luminosity, morphology, colour, etc. Moreover, following to Ref. 3 and Ref. 2, it allowed studying the relation between the topology and properties of galaxies at the large-scaling structure and concluding both cosmological parameters and galaxy formation mechanisms. Also the investigation of galaxies clusters relates to the dependence of the characteristics of galaxies on the surrounding medium properties, and the large-scale structure formation. Thus the cluster system dynamic investigation also should estimate possible DM presence due to analysis of several catalogues – for instance, CfA2 Redshift Survey.\textsuperscript{8, 14, 17} Therefore, the large-scale distribution of matter in the Metagalaxy will be described by analysing quantities of galaxies to various limiting magnitudes and the redshift surveys – see, for example Ref. 5 and Ref. 16.

2. The Second CfA Redshift Survey data analysis

Preliminary results of the investigation of the properties of clusters of galaxies from the second CfA redshift survey were discussed in the presented article.

The second CfA redshift survey was started between 1985 and 1995 due measurements of relative distances via redshifts for about 18000 bright galaxies in the northern sky. It contain data of 1971 galaxies groups (totally 6787 members) at galactic latitudes \( b \geq 20^\circ \) – see Ref. 17.

Early data from this catalogue were analysed in Ref. 15 and Ref. 14 and it were found several peculiarities for clusters \#933, 1242, 88, 142, 1046, 1101 in distributions of group members on absolute magnitude, angular velocity, etc.

The results of additional analysis of these clusters characteristics are discussed in the presented article. The mean values of it’s characteristics are listed in the Table 1 (rows 1 – 5). Several additional peculiarities have found on the distributions of galaxies inside these clusters on magnitude and absolute magnitude on CfA2 data. The examples of such distributions for clusters \#142 and \#88 are presented at figures Fig. 1(a), Fig. 1(b) and Fig. 2(a), Fig. 2(b) correspondingly. Dual structure was separated at distributions of galaxies inside cluster on magnitude and absolute magnitude for these two clusters. Bifurcation points are \( m_{142} = 14.5 \pm 0.2 \) and \( M_{142} = 19.5 \pm 0.2 \) for group \#142, also \( m_{88} = 14.5 \pm 0.2 \) and \( M_{88} = 19.0 \pm 0.2 \) for one \#88.

Thus we have separate clusters of galaxies contain more than 20 members for subsequent analysis. The mean values of characteristics for other 8 clusters from this subsample are listed in the Table 1 (rows 6 – 13). Fig. 3(a), Fig. 4(a) and
Fig. 1. Several peculiarities on the distributions of galaxies inside cluster #142 on CfA2 data. (a) Graph for distribution of galaxies on magnitude. (b) Graph for distribution of galaxies on absolute magnitude.

Fig. 2. Several peculiarities on the distributions of galaxies inside cluster #88 on CfA2 data. (a) Graph for distribution of galaxies on magnitude. (b) Graph for distribution of galaxies on absolute magnitude.

Fig. 6(a) shows the other examples of distributions of galaxies inside cluster with members numbers both than 50 and 20 on magnitude for groups #1046, #933 and #1652 correspondingly. Graphs Fig. 3(b), Fig. 4(b) and Fig. 6(b) represents the distributions of galaxies in these clusters on absolute magnitude. Dual structure also was separated at distributions of galaxies inside cluster on magnitude and absolute magnitude for all investigated clusters without any correlation with members numbers. The obtained bifurcation points in the distributions of galaxies in these clusters on magnitude are $m_{1046} = 13.8 \pm 0.2$, $m_{933} = 14.3 \pm 0.2$, $m_{1652} = 14.9 \pm 0.2$ and ones on absolute magnitude are $M_{1046} = -17.9 \pm 0.2$, $M_{933} = -19.8 \pm 0.2$, $M_{1652} = -20.0 \pm 0.2$. 
Table 1. The mean values of characteristics for several clusters of galaxies on CfA2 data.

<table>
<thead>
<tr>
<th>Cluster number</th>
<th>Amount of galaxies</th>
<th>RQF – Relative quantities false (%)</th>
<th>Heliocentric velocity (km/s)</th>
<th>Mean distance of member of group from its centre (Mpc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1046</td>
<td>337</td>
<td>2.328</td>
<td>1847 ± 519</td>
<td>1.423</td>
</tr>
<tr>
<td>1101</td>
<td>118</td>
<td>0.784</td>
<td>7433 ± 751</td>
<td>1.006</td>
</tr>
<tr>
<td>88</td>
<td>92</td>
<td>1.426</td>
<td>5040 ± 440</td>
<td>1.357</td>
</tr>
<tr>
<td>933</td>
<td>63</td>
<td>0.372</td>
<td>6656 ± 703</td>
<td>0.497</td>
</tr>
<tr>
<td>142</td>
<td>63</td>
<td>0.721</td>
<td>4868 ± 496</td>
<td>0.667</td>
</tr>
<tr>
<td>1242</td>
<td>26</td>
<td>0.406</td>
<td>2750 ± 190</td>
<td>0.384</td>
</tr>
<tr>
<td>1652</td>
<td>28</td>
<td>1.561</td>
<td>9324 ± 427</td>
<td>1.394</td>
</tr>
<tr>
<td>107</td>
<td>34</td>
<td>0.303</td>
<td>1530 ± 395</td>
<td>0.354</td>
</tr>
<tr>
<td>150</td>
<td>20</td>
<td>1.629</td>
<td>4964 ± 323</td>
<td>0.821</td>
</tr>
<tr>
<td>316</td>
<td>21</td>
<td>0.294</td>
<td>6068 ± 269</td>
<td>0.450</td>
</tr>
<tr>
<td>317</td>
<td>23</td>
<td>0.504</td>
<td>6152 ± 288</td>
<td>0.564</td>
</tr>
<tr>
<td>961</td>
<td>27</td>
<td>2.422</td>
<td>1264 ± 167</td>
<td>0.481</td>
</tr>
<tr>
<td>977</td>
<td>20</td>
<td>0.485</td>
<td>6288 ± 402</td>
<td>0.407</td>
</tr>
</tbody>
</table>

Moreover several peculiarities have found on the distributions on angular velocity and absolute magnitude together with distributions on velocity and distance to cluster centre. Such distributions for clusters of galaxies #142 and #88 are presented at Fig. 7(a), Fig. 7(b) and Fig. 8(a), Fig. 8(b) correspondingly. Dual structure was separated on the distributions of galaxies inside cluster on angular velocity and absolute magnitude for these two clusters with bifurcation points similar to results of analysis of Fig. 1(b) and Fig. 2(b). Also dual structure appear on the distributions on velocity and distance to cluster centre with bifurcation points $R_{c142} = 0.70 ± 0.05$ and $R_{c88} = 1.00 ± 0.05$ for clusters #142 and #88.

Fig. 3. Several peculiarities on the distributions of galaxies inside cluster #1046 on CfA2 data. (a) Graph for distribution of galaxies on magnitude. (b) Graph for distribution of galaxies on absolute magnitude.
Fig. 4. Several peculiarities on the distributions of galaxies inside cluster #933 on CfA2 data. (a) Graph for distribution of galaxies on magnitude. (b) Graph for distribution of galaxies on absolute magnitude.

Fig. 5. Several peculiarities on the distributions of galaxies inside cluster #142 on CfA2 data. (a) Graph for distribution of galaxies on angular velocity and absolute magnitude. (b) Graph for distribution of galaxies on velocity and distance to cluster centre.

The distributions on angular velocity and absolute magnitude groups #1046, #933 and #1652 are presented at Fig. 9(a), Fig. 10(a) and Fig. 6(a) correspondingly. Dual structure reveals on these figures with bifurcation points similar to results of analysis of Fig. 3(a), Fig. 4(a) and Fig. 6(a) look like clusters #142 and #88. Moreover dual structure appear on the distributions on velocity and distance to cluster centre with bifurcation points $R_{C1046} = 1.7 \pm 0.1$, $R_{C933} = 0.52 \pm 0.05$ and $R_{C1652} = 1.5 \pm 0.1$ for clusters #1046, #933 and #1652 correspondingly.

The spatial distribution of galaxies in listed in the Table 1 clusters were analysed. Figure 12(a) represents such distribution for cluster #1046. Dual structure
Fig. 6. Several peculiarities on the distributions of galaxies inside cluster #1652 on CfA2 data. (a) Graph for distribution of galaxies on magnitude. (b) Graph for distribution of galaxies on absolute magnitude.

Fig. 7. Several peculiarities on the distributions of galaxies inside cluster #142 on CfA2 data. (a) Graph for distribution of galaxies on angular velocity and absolute magnitude. (b) Graph for distribution of galaxies on velocity and distance to cluster centre. Shaded regions correspond areas from right side of bifurcation points on Fig. 1.

were separated inside this cluster accordingly to preliminary analysis results — see Fig. 12(b). Similar peculiarities have found on the spatial distributions for other clusters. The examples are presented at Fig. 13, Fig. 14 and Fig. 15.

The results of preliminary data analysis have shown that the distributions on groups members position, magnitude, absolute magnitude, angular velocity and absolute magnitude also with ones on velocity and distance to cluster centre and represent two areas for clusters #88, 1101, 1046, 142, 933, 1242, 1652, 107, 150, 316, 317, 961 and 977. Redshifts of these clusters are in the region 0.002 – 0.032.
Fig. 8. Several peculiarities on the distributions of galaxies inside cluster #88 on Cfa2 data. (a) Graph for distribution of galaxies on angular velocity and absolute magnitude. (b) Graph for distribution of galaxies on velocity and distance to cluster centre. Shaded regions correspond areas from right side of bifurcation points on Fig. 2.

Fig. 9. Several peculiarities on the distributions of galaxies inside cluster #1046 on Cfa2 data. (a) Graph for distribution of galaxies on angular velocity and absolute magnitude. (b) Graph for distribution of galaxies on velocity and distance to cluster centre. Shaded regions correspond areas from right side of bifurcation points on Fig. 3.

Galaxies from these areas are paired accordingly its spectral characteristics and position. Unfortunately direct data analysis not allow understanding of reality of such dual structure because it could be caused by several selection effects.

Let’s try to investigate dynamic of these systems using Nonlinear Time Series Analysis methods – see, for instance, Ref. 9. Unfortunately real time variables are absent in the analysed systems. But dynamic behavior of cluster’s members strongly depend of its velocities and distances to cluster centre. We have construct phase space cluster of galaxies #88 using values of redshift, coordinates, magnitude,
absolute magnitude and distance to centre. We have use ratio between distance to centre and tangential velocity as time similar variable in the presented article and constructed simple attractors in this phase space for first attempt of investigation of dynamic of system. Let’s separate basins of attractors correspondingly to bifurcation points on the analysable distributions. Accordingly to preliminary results of analysis we have obtained two attractors in the phase space of cluster #88 which concludes real dual structure of this system. Figure 16 represents three dimension projection of obtained attractors.
Fig. 12. The spatial distributions of galaxies for cluster #1046 on CfA2 data (a) and dual structure appearance on this distribution (b).

Fig. 13. The spatial distributions of galaxies for cluster #142 on CfA2 data (a) and dual structure appearance on this distribution (b).

Fig. 14. The spatial distributions of galaxies for cluster #142 on CfA2 data (a) and dual structure appearance on this distribution (b).
Fig. 15. The spatial distributions of galaxies for several clusters on CfA2 data. (a) Graph for cluster #933. (b) Graph for cluster #1652.

Fig. 16. The projections of six-dimensional system of attractors for cluster #88. (a) Projection in three-dimension space with axes corresponds to coordinates and redshift. (b) Two dimension projection with axes corresponds to RA and redshift.

3. Conclusions

Preliminary results of the properties of 13 clusters of galaxies from CfA2 redshift survey (##88, 1101, 1046, 142, 933, 1242, 1652, 107, 150, 316, 317, 961, 977) are presented. Redshifts of these clusters are in the region 0.002 – 0.032. The distributions on magnitude, absolute magnitude and angular velocity, etc represent two areas for these clusters. Galaxies from these areas are paired accordingly its spectral...
characteristics and position. Also several anomalies of spatial dynamic of galaxies in these clusters were separated.

The presence of such structure allows conclude two alternatives. In the first one dark matter presence inside cluster in configuration similar to Zeldovich pancake. Second case is gravitational lensing on compact object or dark matter blob located between galaxy cluster and observer.

Also several peculiarities have found on the spatial distributions of galaxies in clusters##933, 142, 1046, and 1652. Moreover, groups ##933, 142, 1046, and 1652 reveals associations with high-energy gamma-emission sources on Fermi/LAT 10-Year Point Source Catalog 4FGL DR2 data (4FGLJ1144.9+1937, 4FGLJ0152.2+3714, 4FGLJ1230.8+1223 and 4FGLJ1653.8+3945 correspondingly).

Furthermore, 4FGLJ1144.9+1937 and 4FGLJ1230.8+1223 observed in subTeV energy band by VERITAS data.

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 influence to groups characteristics (gravitational lensing or object inside cluster) 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 $\sim 0.01^\circ$ at $E_\gamma = 100 \text{ GeV}$ and upper energy band boundary about several $\text{TeV}$. Also now the coordination of multiwavelength observations program of Cherenkov Telescope Array (CTA) and GAMMA-400 is discussed.

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