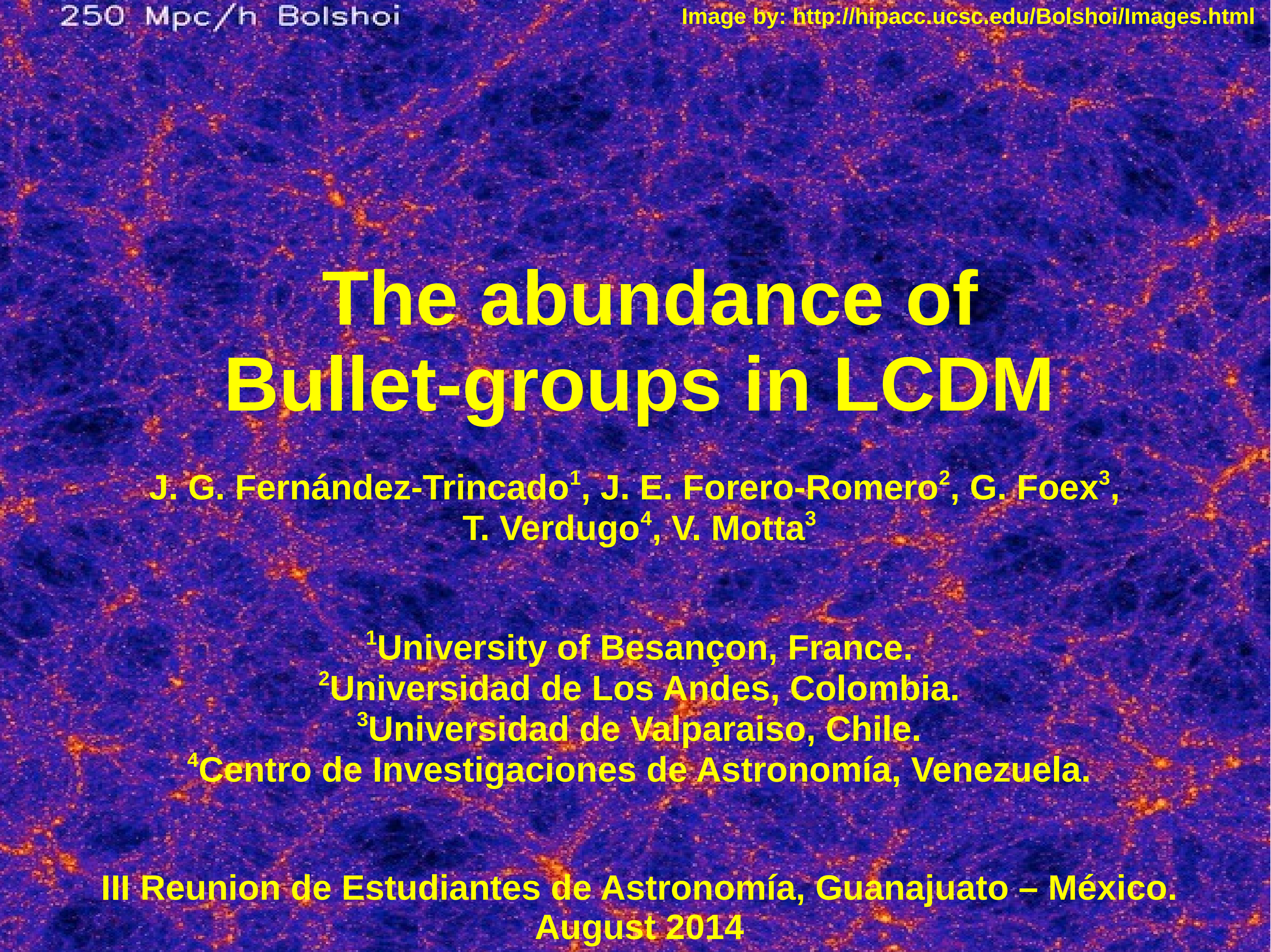


Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html

The abundance of Bullet-groups in LCDM

J. G. Fernández-Trincado[1], J. E. Forero-Romero[2], G. Foex[3], T. Verdugo[4], V. Motta[3]

[1]University of Besançon, France.
[2]Universidad de Los Andes, Colombia.
[3]Universidad de Valparaiso, Chile.
[4]Centro de Investigaciones de Astronomía, Venezuela.

III Reunion de Estudiantes de Astronomía, Guanajuato – México.
August 2014

Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html

ABSTRACT

We estimate the expected distribution of displacements between the two dominant dark matter (DM) peaks (DM-DM displacements) and between DM and gaseous baryon peak (DM-gas displacements) in dark matter halos with masses larger than $10^{13}h^{-1}\mathrm{M}_{\odot}$. We use as a benchmark the observation of SL2S J08544-0121, which is the lowest mass system ($1.0 \times 10^{14}h^{-1}\mathrm{M}_{\odot}$) observed so far featuring a bi-modal dark matter distribution with a dislocated gas component. We find that $(50 \pm 10)\%$ of the dark matter halos with circular velocities in the range $300\,\mathrm{km\ s}^{-1}$ to $700\,\mathrm{km\ s}^{-1}$ (groups) show DM-DM displacements equal or larger than $186 \pm 30h^{-1}$kpc as observed in SL2S J08544-0121. For dark matter halos with circular velocities larger than $700\,\mathrm{km\ s}^{-1}$ (clusters) this fraction rises to $(70 \pm 10)\%$. Using the same simulation we estimate the DM-gas displacements and find that 0.1 to 1.0% of the groups should present separations equal or larger than $87 \pm 14h^{-1}$kpc corresponding to our observational benchmark; for clusters this fraction rises to $(7 \pm 3)\%$, consistent with previous studies of dark matter to baryon separations. Considering both constraints on the DM-DM and DM-gas displacements we find that the number density of groups similar to SL2S J08544-0121 is $\sim 6.0 \times 10^{-7}$ Mpc^{-3}, three times larger than the estimated value for clusters. These results open up the possibility for a new statistical test of ΛCDM by looking for DM-gas displacements in low mass clusters and groups.

See more details in Fernández-Trincado et al. (2014a)

Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html

We use the Bolshoi Run, a cosmological Dark Matter only simulation over a cubic volumen of $250h^{-1}$ Mpc.

$$z = 80 \rightarrow z = 0$$

More details in http://www.multidark.org/MultiDark/

The Bolshoi simulation is the most accurate cosmological simulation of the evolution of the large-scale structure of the universe yet made (“bolshoi” is the Russian word for “great” or “grand”).

More details in http://www.multidark.org/MultiDark/

Our Sample

[1] Host halos (halos that are not inside a larger halo) with circular velocities Vc ≥ 300 km s^{-1} (≥ 1 x $10^{13}h^{-1}$ M_{sun})

[2] Sub-halos with circular velocities Vc ≥ 75 km s^{-1} (≥ 5 X $10^{10}h^{-1}$ M_{sun})

[3] Finally, we associate each host halo to its most massive sub-halo

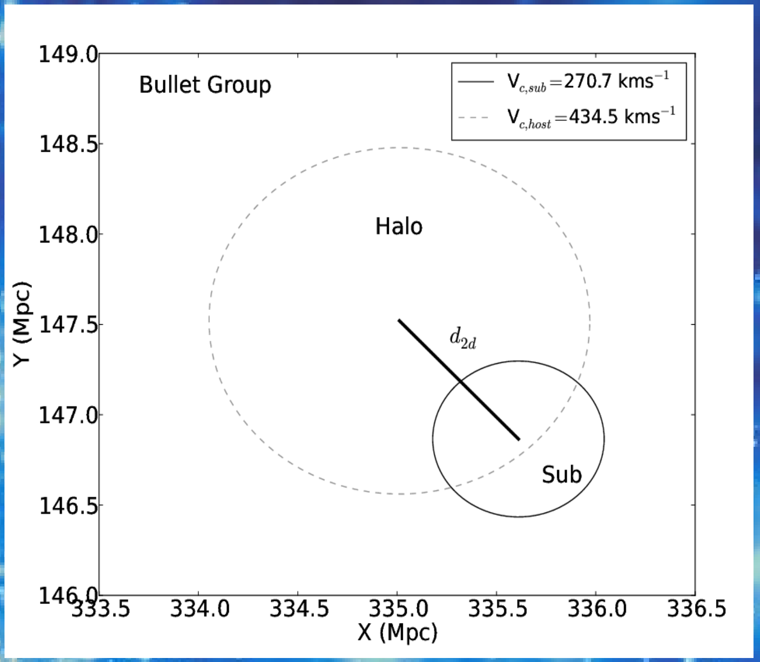
Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html

Bullet Geometry

$$\vec{v} = \vec{v}_{\rm sub} - \vec{v}_{\rm host}$$

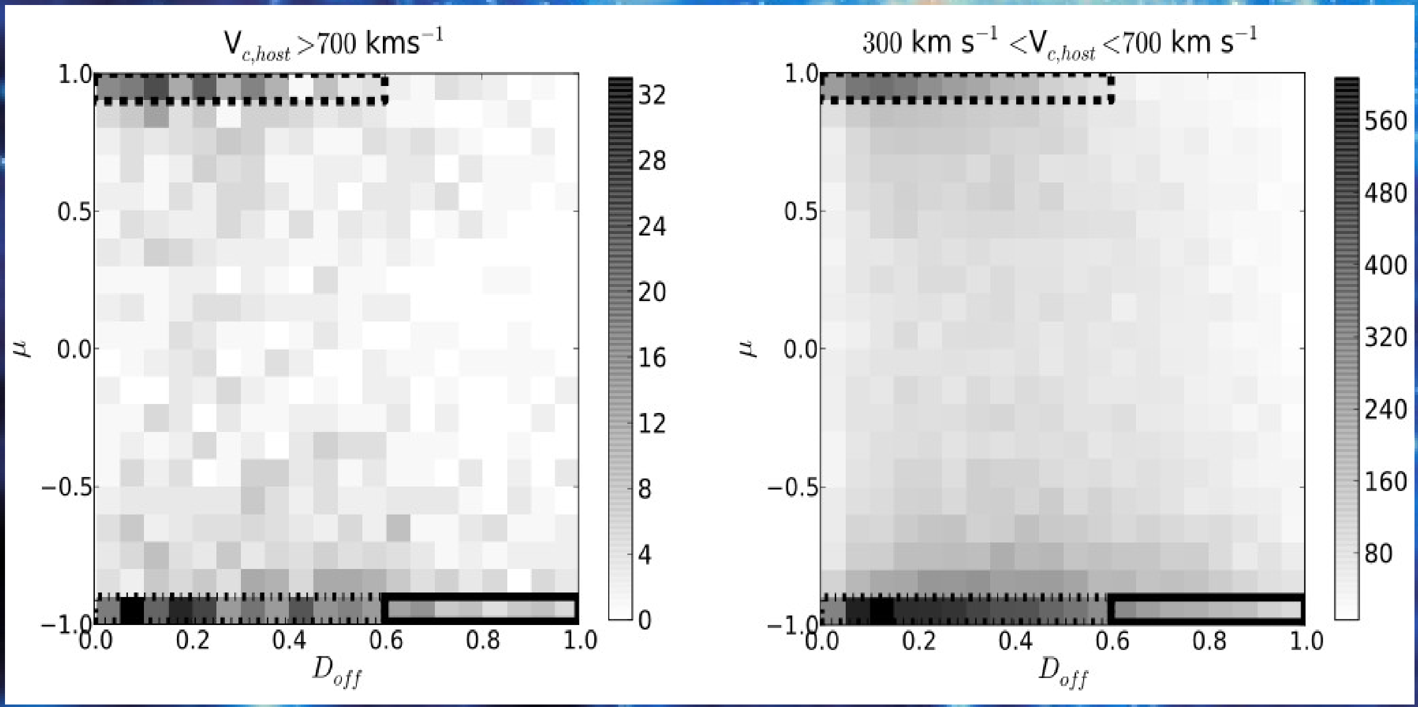
$$\vec{r} = \vec{r}_{\rm sub} - \vec{r}_{\rm host}$$

$$\mu \equiv \cos(\theta) = \frac{\vec{v} \cdot \vec{r}}{||\vec{v}||\, ||\vec{r}||}$$



Results

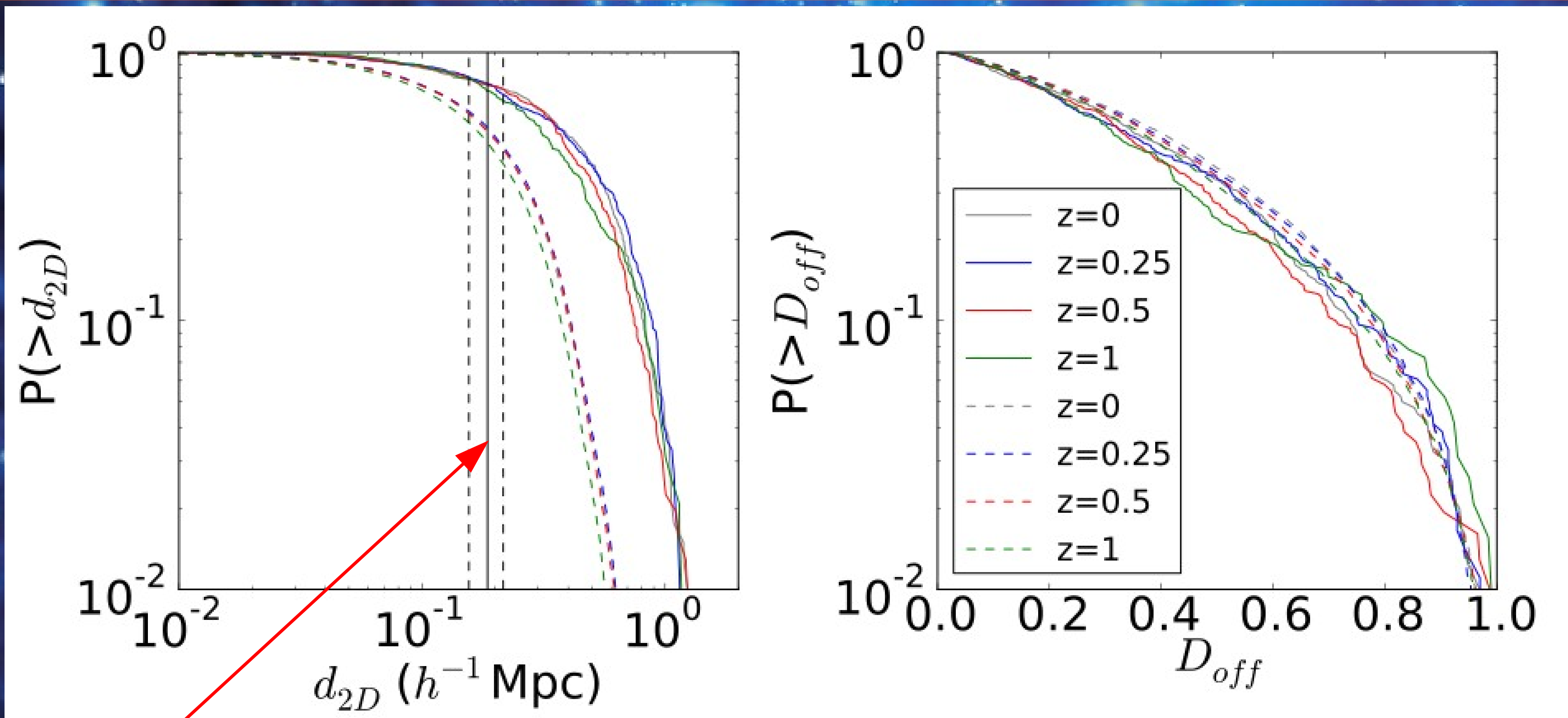
$$D_{\rm off} = ||\vec{r}||_{\rm 2D} / R_{\rm vir}$$



Three main stages in a Bullet-like enconunter with |μ| ~ 1. First, when the sub-halo crosses the virial radius of the host starting a head on collision Doff ~1 and μ ~-1. Second, as the sub-halo crosses for first time the center of the host halo Doff<1.0 and μ ~1. Third, as the sub-halo reaches apogee and comes back to the center of the halo Doff < 1.0 and μ ~ 1.

Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html

Dark Matter – Dark Matter displacements

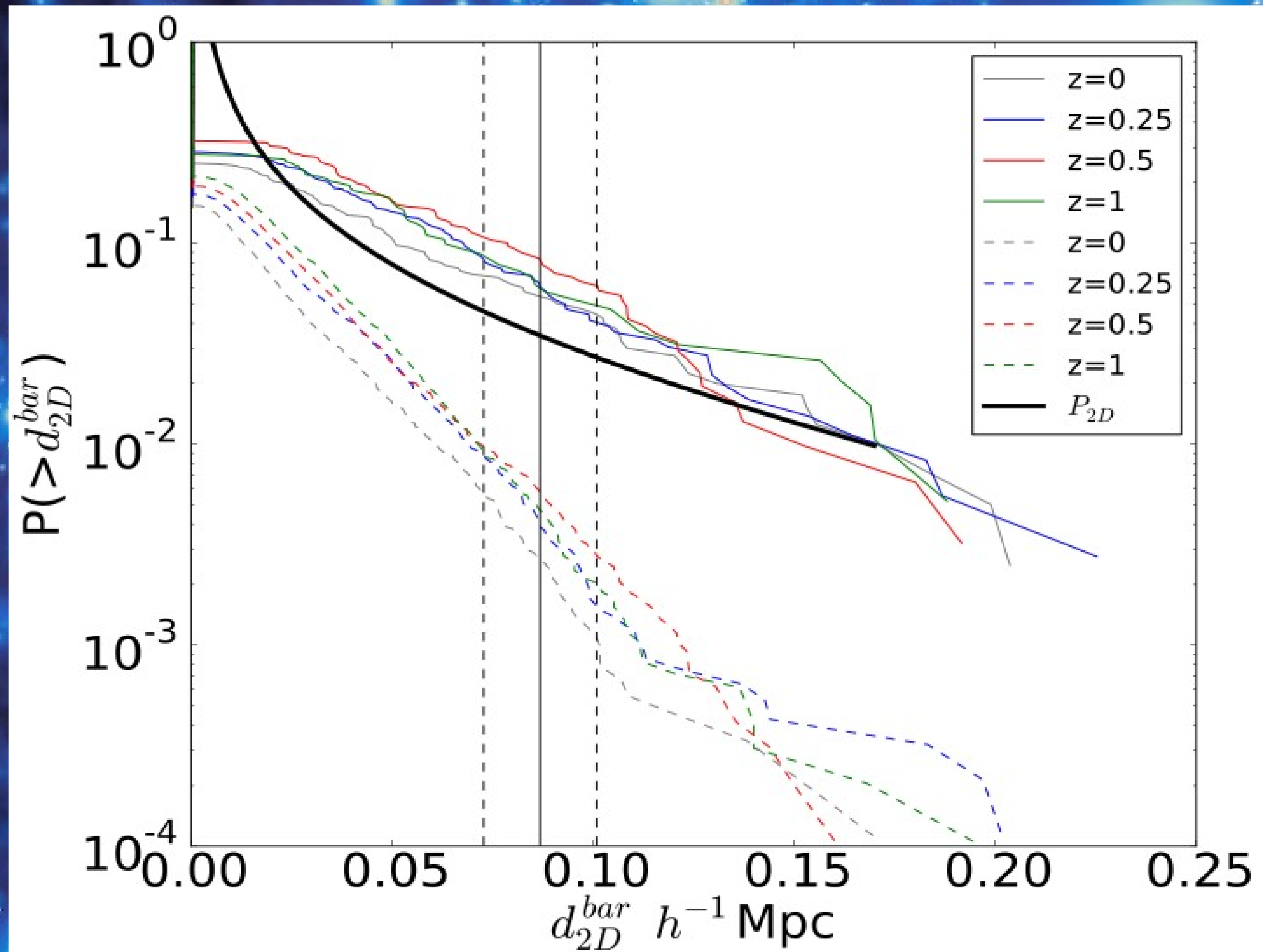


(186±30) h^{-1}kpc = mean value and uncertainties in the separation between the two dark matter clumps estimated in Gastaldello et al. (2014) for the SL2S J08544-0121.

Between 40% to 60% of the groups show a displacement equal or larger than this observational benchmark. This fraction rises to 60% and 80% in clusters.

Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html

Dark Matter – Gas displacements



$$X_{\rm off} = ||\vec{r}_{min} - \vec{r}_{cm}|| / R_{\rm vir}$$

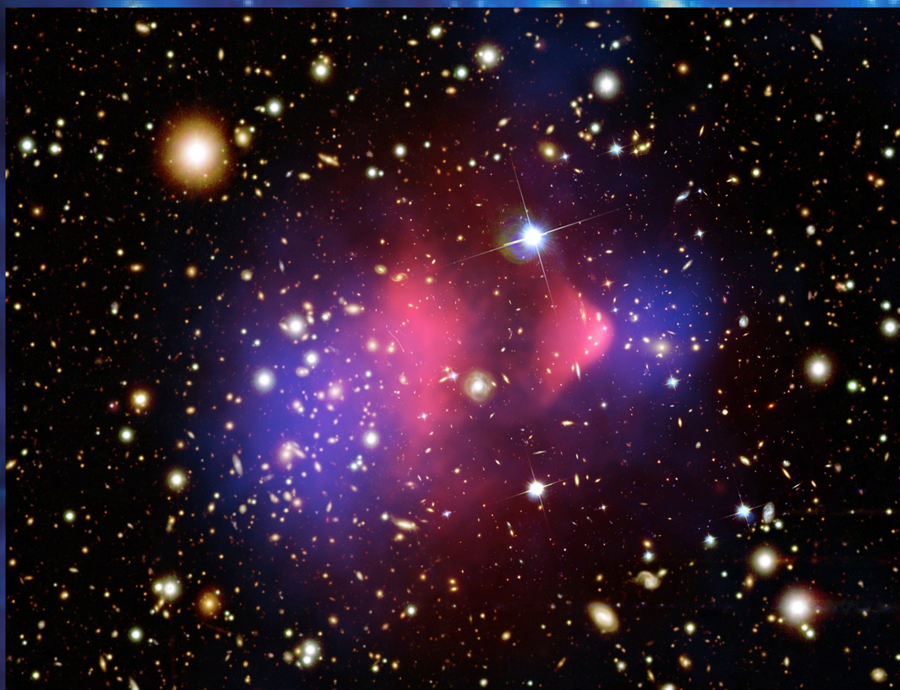
$$d_{\rm 2D}^{\rm bar} = X_{\rm off} R_{\rm vir}$$

Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html

Bullet Cluster

z=0.3

Mass = $1.9 \times 10^{15} M_{\odot}$



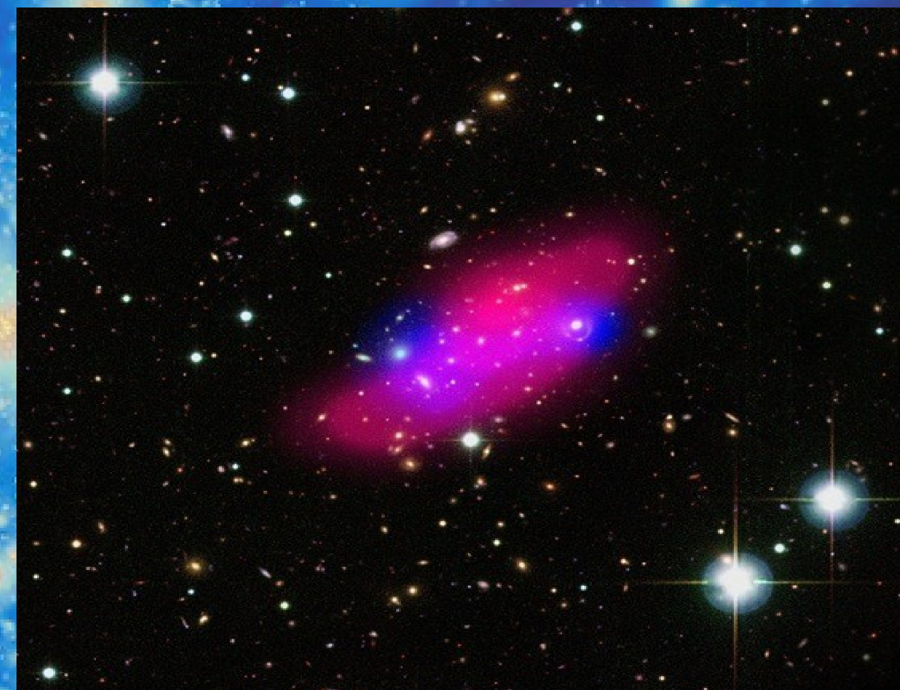
The group of galaxies is known as 1E 0657-56

Markevitch, M. (2006)

Bullet Group

z=0.351

Mass = $2.4 \pm 0.6 \times 10^{14}\ \mathrm{M}_{\odot}$



The group of galaxies is known as SL2S J08544-0121

Gastaldello, et al. (2014)


Image by: http://hipacc.ucsc.edu/Bolshoi/Images.html
62 Mpc/h Bolshoi
31 Mpc/h Bolshoi
15.5 Mpc/h Bolshoi
Thanks you very much!!!
3.9 Mpc/h Bolshoi
Coma 1.9 Mpc/h Bolshoi