



Era of the great walls:
the BOSS Great Wall and the Sloan Great Wall
or
The challenge of the largest structures in the Universe

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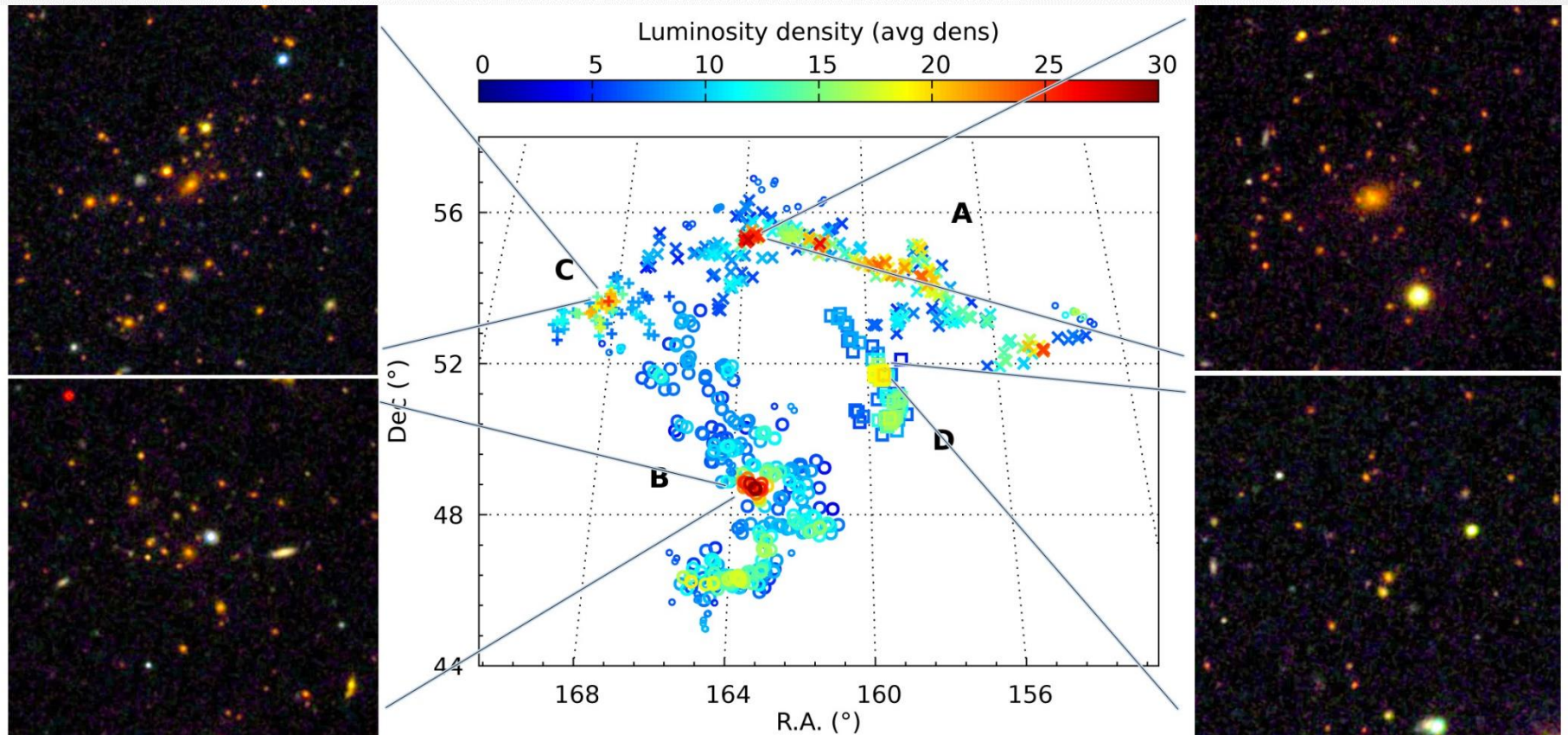
I thank my coauthors:

Heidi Lietzen, Mirt Gramann,
Enn Saar, Lauri Juhan Liivamägi,
Elmo Tempel,
Pekka Heinämäki, Pasi Nurmi,
Jaan Einasto, Changbom Park
and others

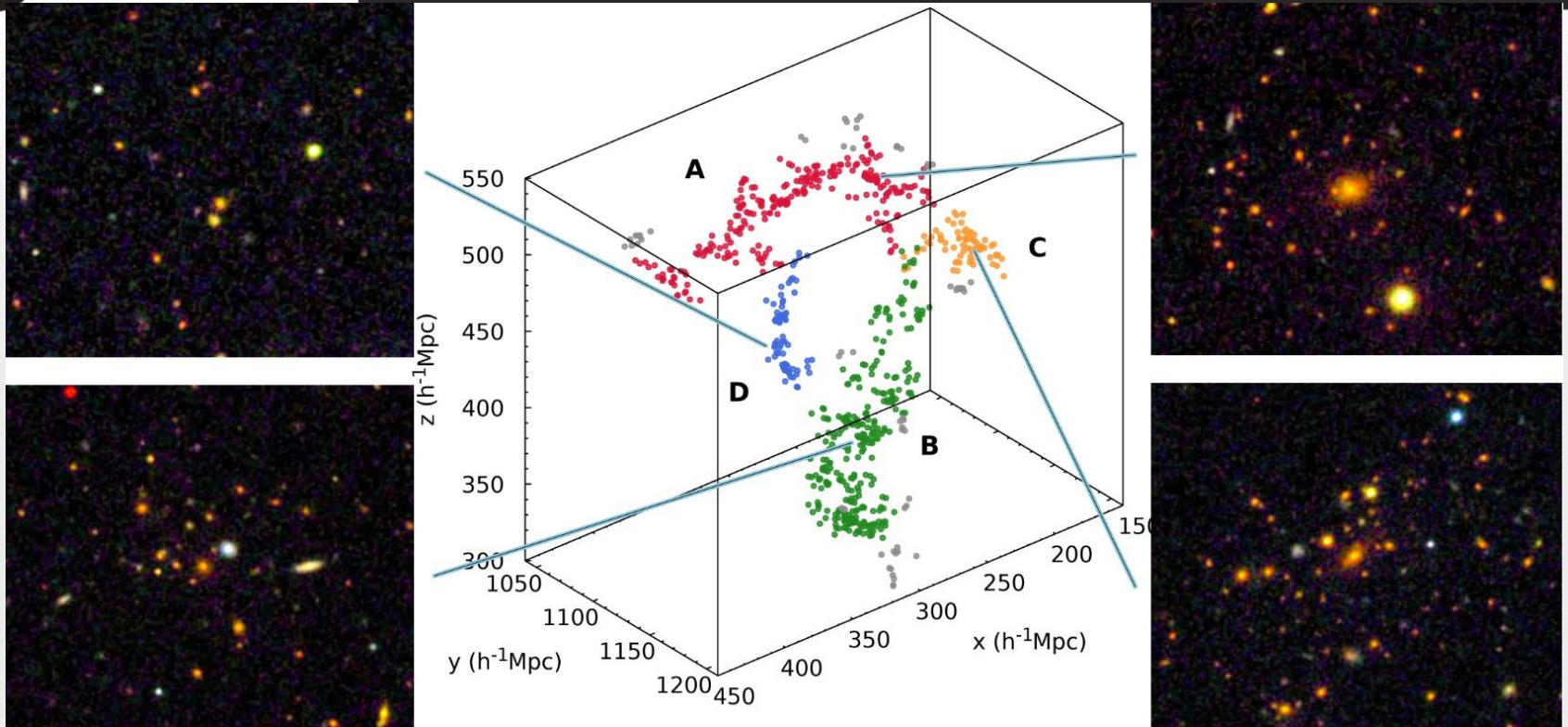
The richest superclusters and their complexes are the largest objects in the dark matter and dark energy dominated Universe - extreme objects to study the evolution of the cosmic web at large scales and to test cosmological models.

Superclusters or their high-density cores – the largest objects in the Universe which may collapse now or in the future;
dynamically active environment to study the evolution of galaxies, galaxy groups, and filaments in them.

The BOSS Great Wall at $z = 0.47$



H. Lietzen, E. Tempel, L. J. Liivamägi, A. Montero-Dorta, M. Einasto,
A. Streblyanska, C. Maraston, J. A. Rubiño-Martín and E. Saar.
A&A Letters, Volume 588, L4, 2016.



BGW: four superclusters: $2 \times \sim 180 h^{-1} \text{ Mpc}$ (A, B) and $2 \times \sim 80 h^{-1} \text{ Mpc}$ (C, D),
 ~ 800 galaxies with $M^* > 10^{10.3} h^{-1} M_{\odot}$

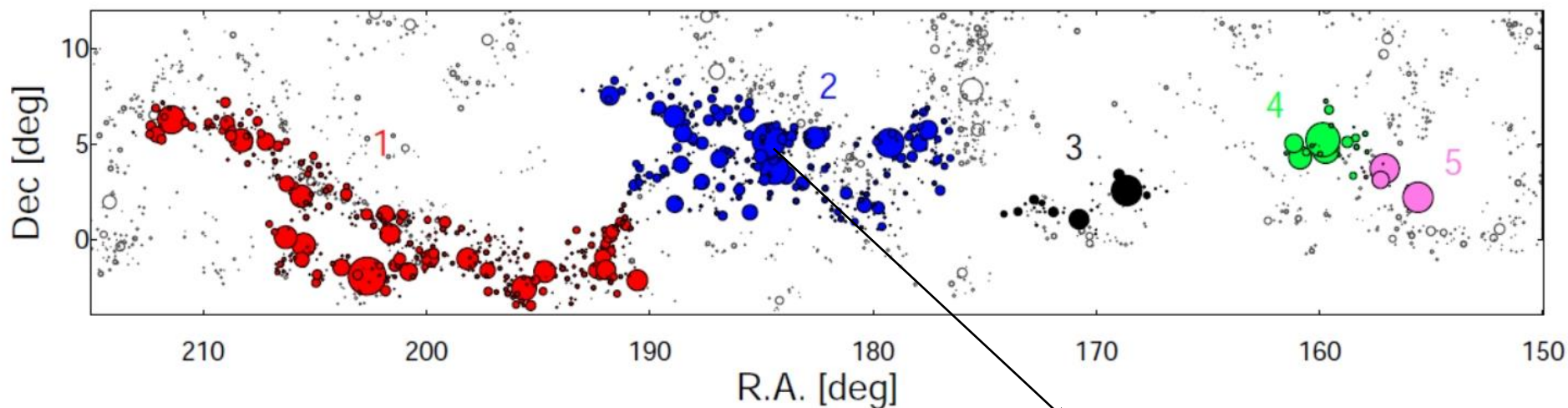
Two Planck clusters

Total mass of the BGW: $\sim 2 \times 10^{17} h^{-1} M_{\odot}$

size: over $270 h^{-1} \text{ Mpc}$

The richest supercluster complex found so far

The Sloan Great Wall

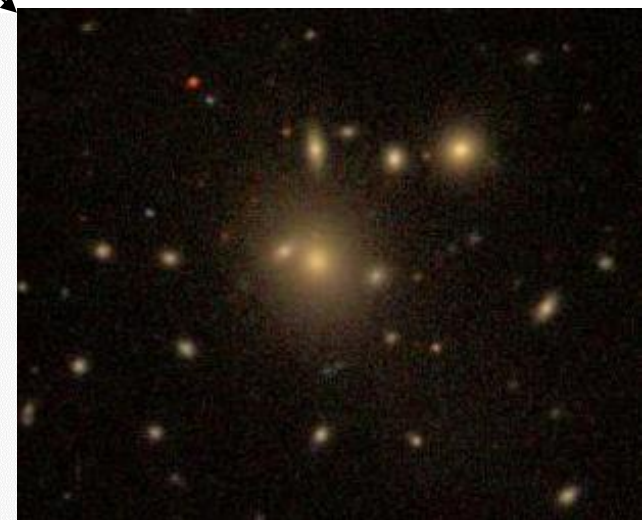


Vogeley et al. (2004), Gott et al. (2005)

see also Einasto et al. 2003, 2008, 2010,
2011, 2014

Park et al. (2012)

Sheth and Diaferio (2011)



Aims:

We determine the mass of the SGW superclusters;

Analyse the structure of the SGW superclusters and find their high-density cores;

Study the mass distribution in the core regions and compare it with the predictions of the spherical collapse model, to find whether the core regions of superclusters may be collapsing.

Data:

Supercluster catalogue:

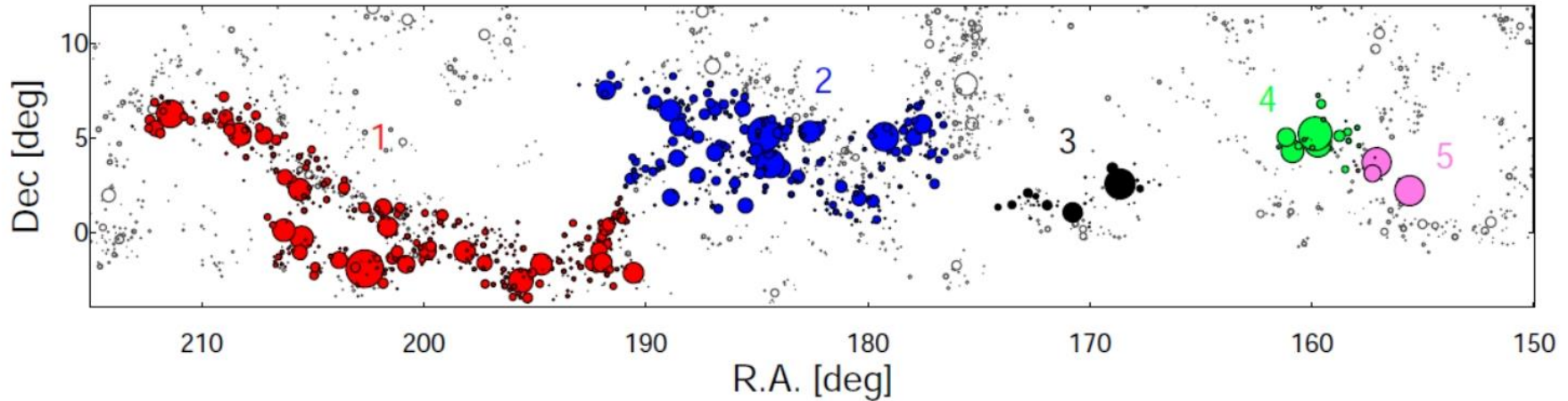
Liivamägi et al., 2012, A&A 539, A80

Group catalogue (with data on group masses and list of member galaxies):

Tempel et al. 2014, A&A 566, A1

Stellar masses of galaxies: SDSS database

The Sloan Great Wall superclusters



(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
No.	Name	ID	N_{gal}	N_1	N_{2-9}^{gr}	N_{10}^{gr}	Dist.	Diam.	$D8_{\text{max}}$	Vol.	L_{tot}
1	SCl 027	202-001+008	3222	706	381	50	255.6	107.0	14.0	25.9	51.6
2	SCl 019	184+003+007	2060	456	274	33	230.4	56.4	15.0	14.4	29.2
3	SCl 0499	168+002+007	408	60	26	7	227.7	34.1	7.5	2.0	4.77
4	SCl 0319	159+004+006	245	30	23	3	206.2	21.4	7.5	1.4	2.16
5	SCl 1109	157+003+007	120	4	5	3	219.2	12.1	5.2	0.2	1.49
SGW			6055	1256	709	96				43.9	89.22

The Sloan Great Wall superclusters: masses

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
No.	Name	M_{dyn} $10^{15} h^{-1} M_{\odot}$	$M_{\text{tot}}^{\text{g}}$ $10^{15} h^{-1} M_{\odot}$	M^* $10^{13} h^{-1} M_{\odot}$	$M^*/M_{\text{tot}}^{\text{g}}$	M_{tot}^* $10^{15} h^{-1} M_{\odot}$	$M_{\text{tot}}^{*\text{g}}$ $10^{15} h^{-1} M_{\odot}$	$M_{\text{tot}}^{\text{g}}/L$ $h M_{\odot}/L_{\odot}$
1	SCI 027	10.41	14.00	16.61	0.012	11.13	12.24	271
2	SCI 019	5.42	7.03	9.09	0.013	6.41	7.05	241
3	SCI 0499	1.41	1.74	1.69	0.010	1.15	1.27	365
4	SCI 0319	0.66	0.82	0.87	0.011	0.76	0.84	380
5	SCI 1109	0.56	0.63	0.69	0.011	0.29	0.32	423
	SGW	18.46	24.22	28.95	0.012	19.74	21.71	272

M_{dyn} = sum of group masses from Tempel et al. 2014

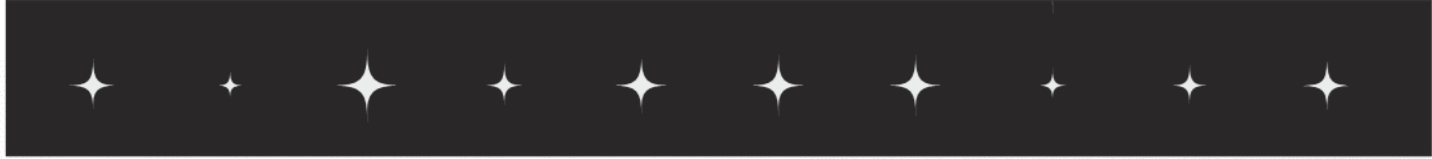
$M_{\text{tot}}^{\text{g}} = M_{\text{dyn}} + M_{\text{faint groups}} + M_{\text{ICM}}$

M^* = sum of stellar masses of galaxies

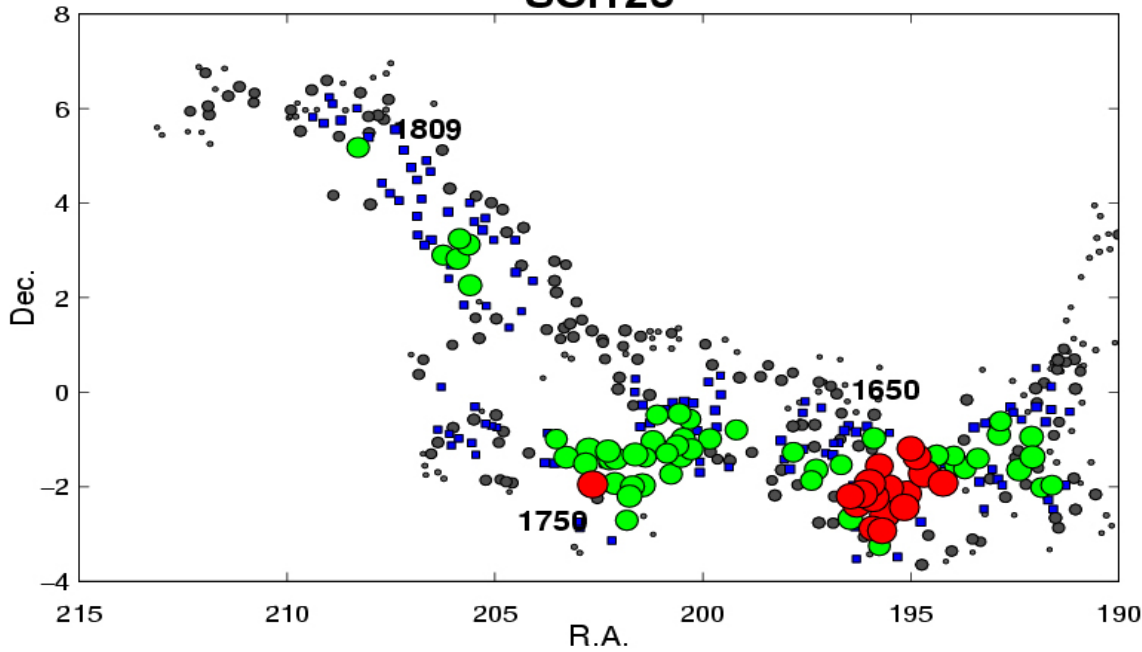
$M^*/M_{\text{tot}}^{\text{g}}$ stellar mass fraction

$M_{\text{tot}}^* = \text{sum of halo masses from stellar masses of galaxies (Moster et al. 2010)}$

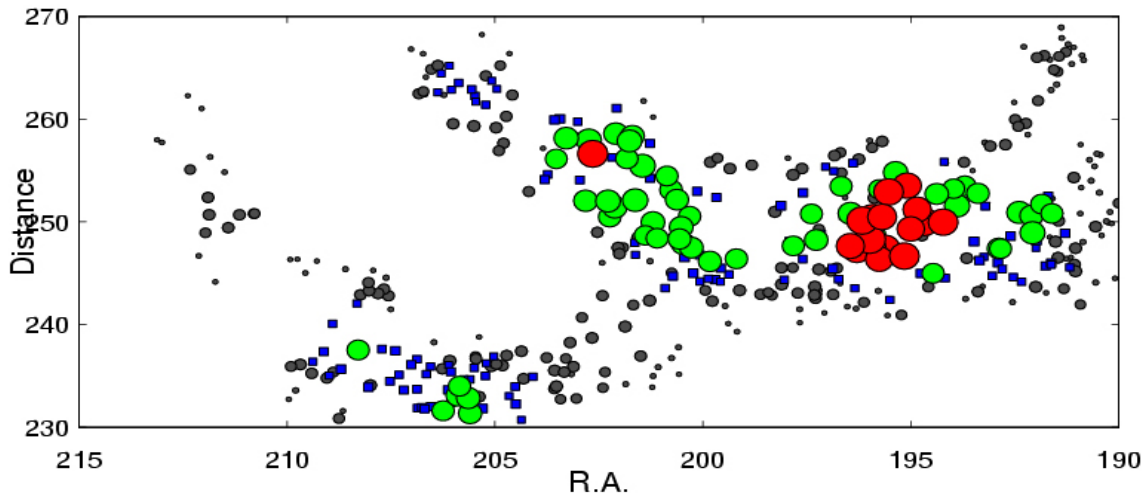
$M_{\text{tot}}^{*\text{g}} = M_{\text{tot}}^* + M_{\text{ICM}}$

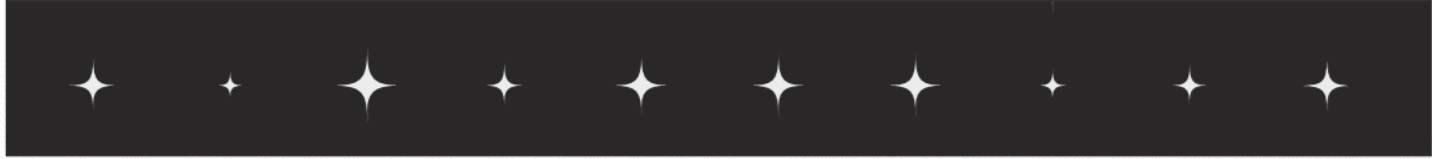


SCI126



SCI 027





Structure of superclusters: components is superclusters with normal mixture modelling

Mclust package in R statistical environment

Input data:

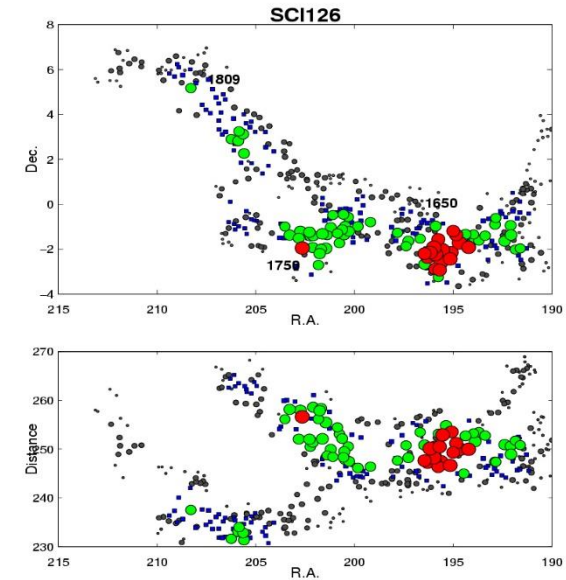
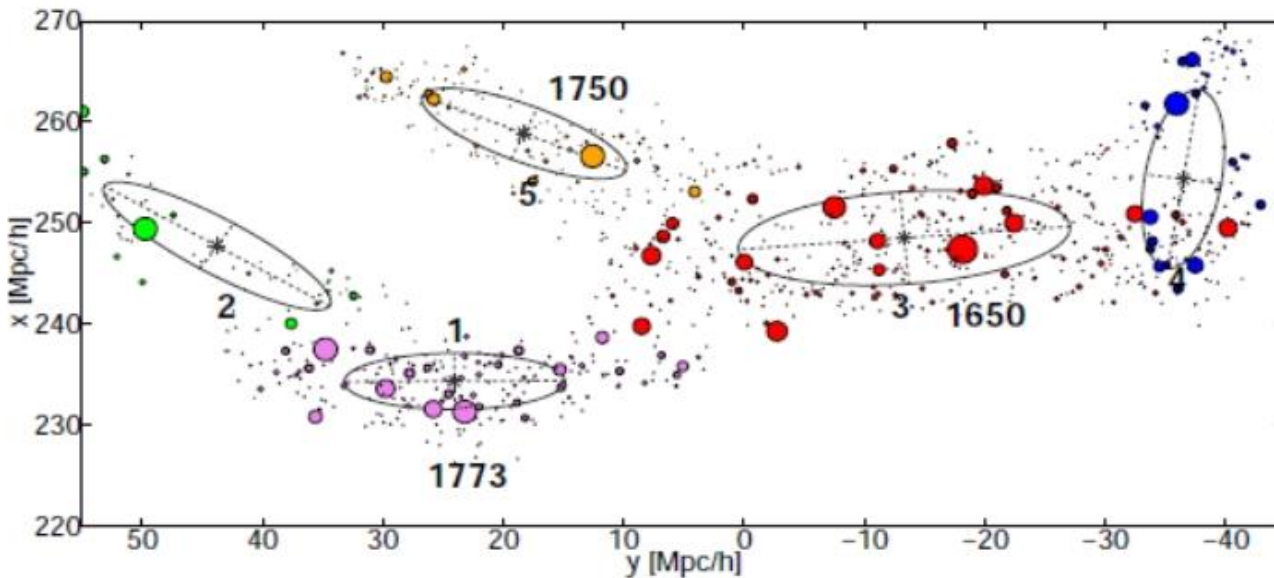
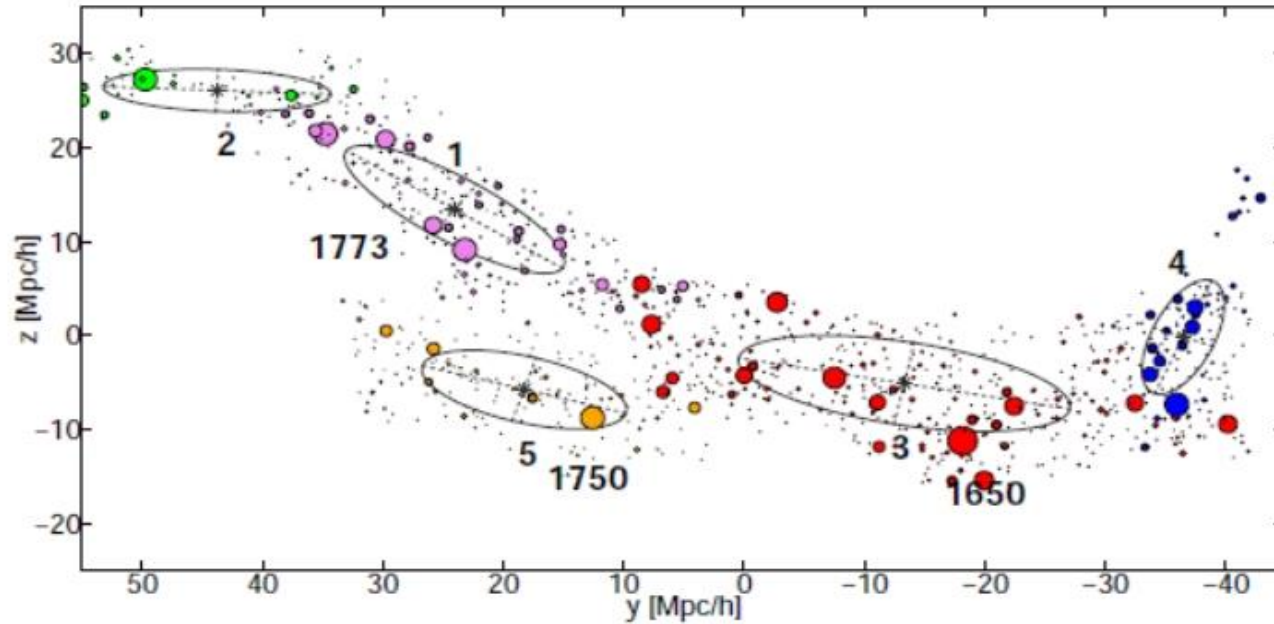
coordinates and distances of galaxy groups and single galaxies (faint groups) in superclusters

Output:

Component number for each group and single galaxy;

Calculate:

Centre coordinates, size, mass, mean luminosity density and other parameters for each component.



SCl 027
components:
high-density cores
(A1650, A1750, A1773),
outskirts regions

Spherical collapse model

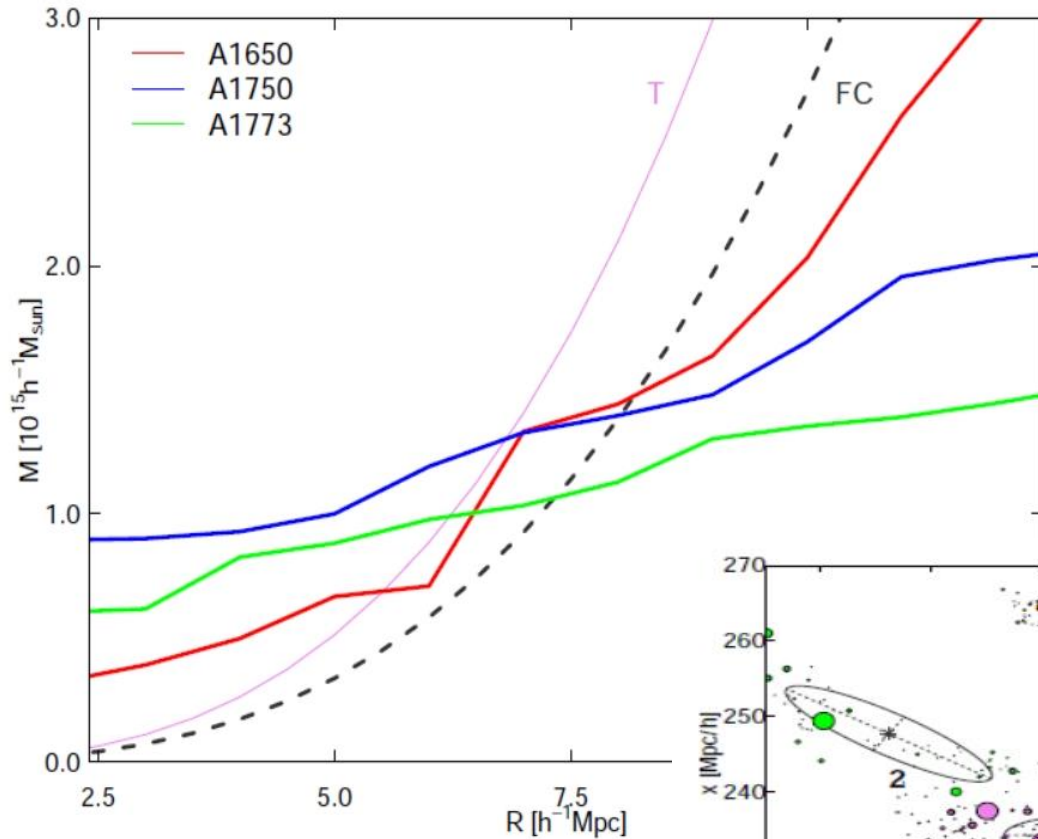
The spherical collapse model describes the evolution of spherically symmetric perturbation in an expanding universe under influence of the gravitational attraction (dark matter), and antigravity of the dark energy.

1. Turnaround: the collapse begins, $\Delta\rho = 13.1$
2. Future collapse: collapse in the distant future, $\Delta\rho = 8.73$

Mass of the structure:

$$M(R) = 1.45 \cdot 10^{14} \Omega_m \Delta\rho (R/5 \text{ h}^{-1} \text{ Mpc})^3 \text{ h}^{-1} M_\odot$$

Gramann et al. 2015, Enn Saar



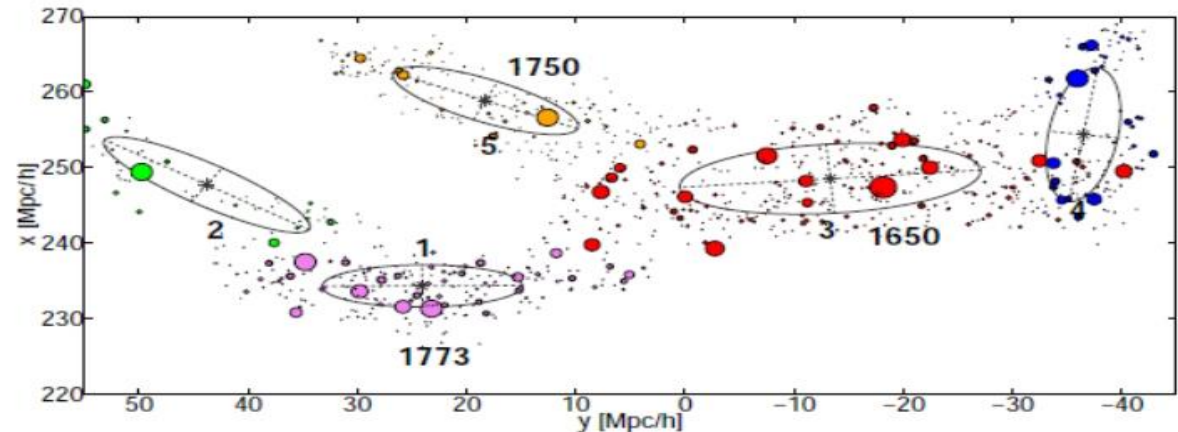
Mass distribution around rich clusters in high-density cores of SCl027

$$M = M_{\text{gr,dyn}} + M_{\text{faint groups}} + M_{\text{ICM}}$$

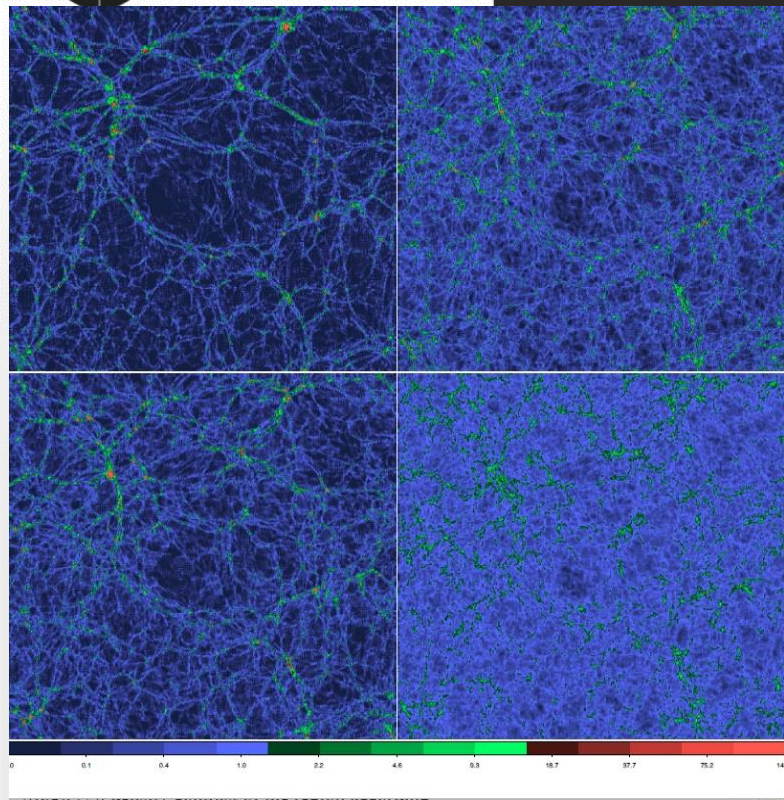
T – turnaround

FC - future collapse

spherical collapse model

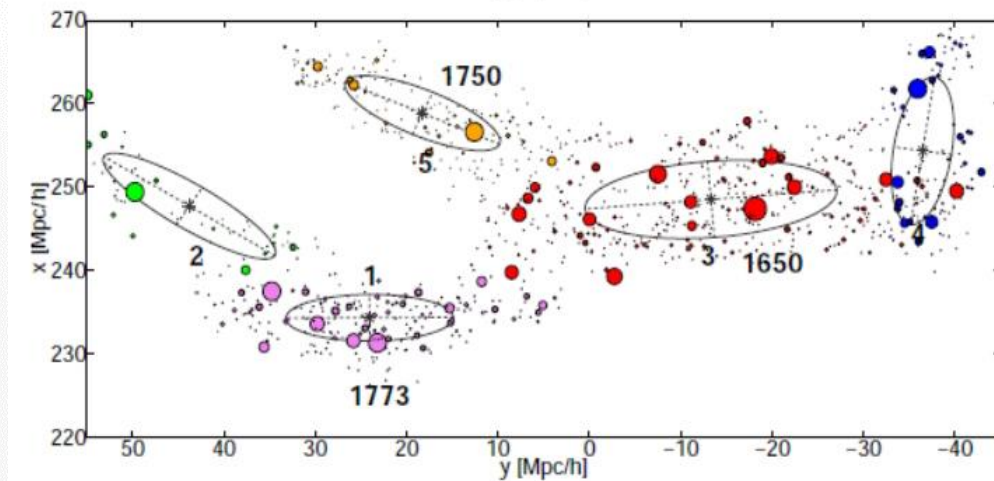


Central parts of the high-density cores ($< 10 \text{ Mpc } h^{-1}$) or perhaps full core regions ($30 - 60 \text{ Mpc } h^{-1}$) – collapsing now or in the future

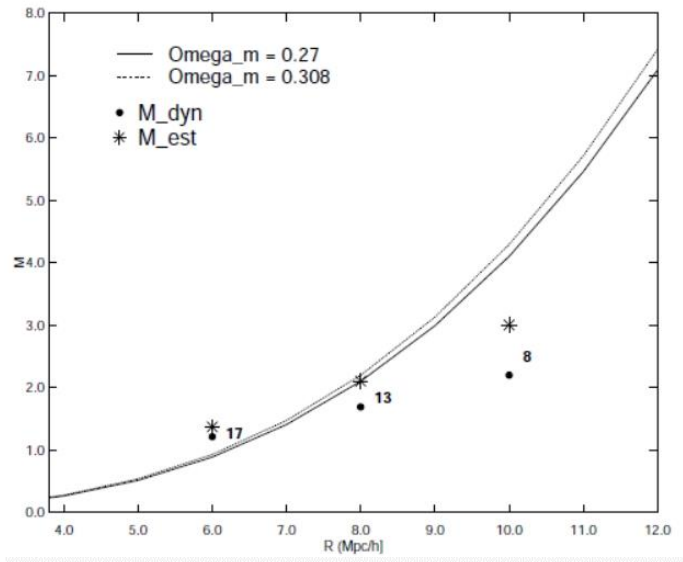
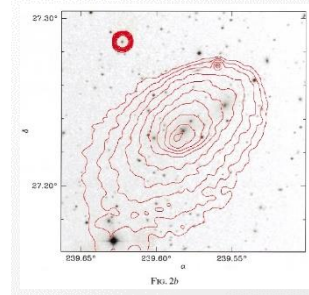
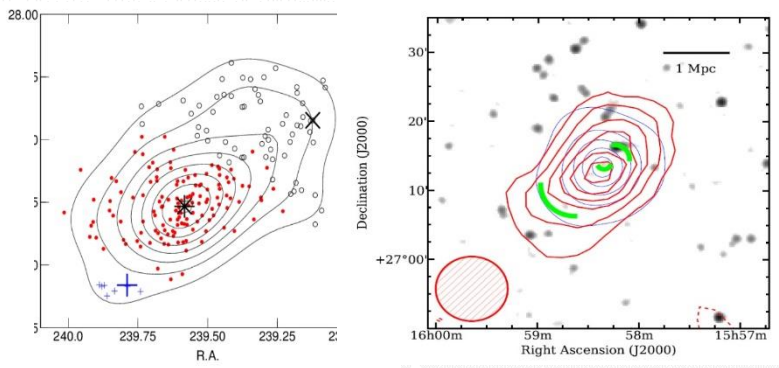
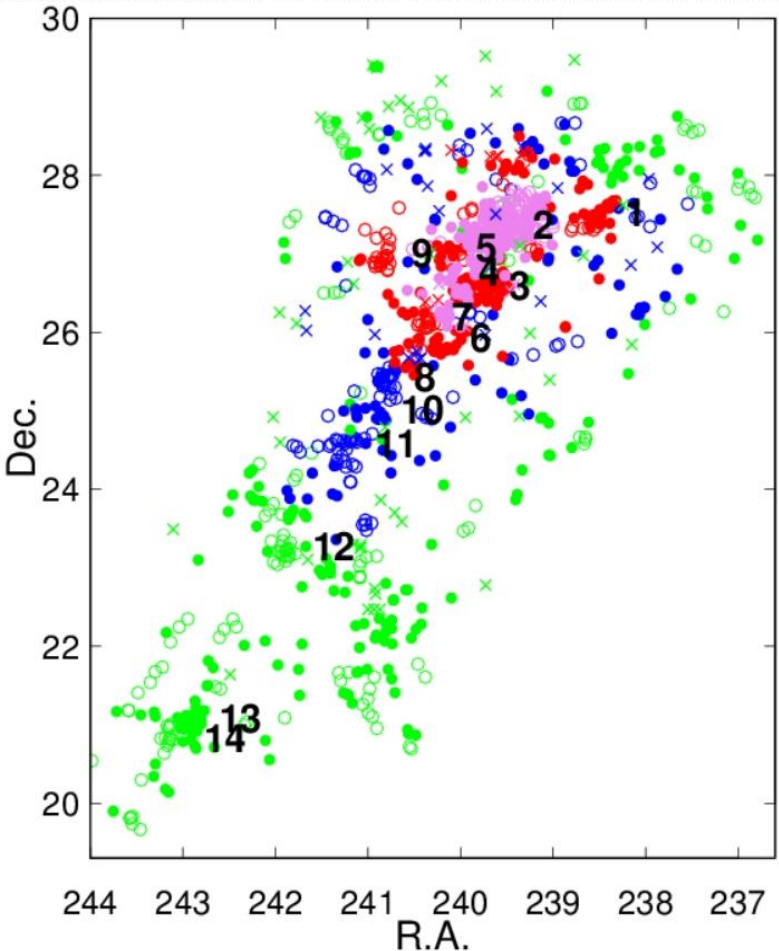
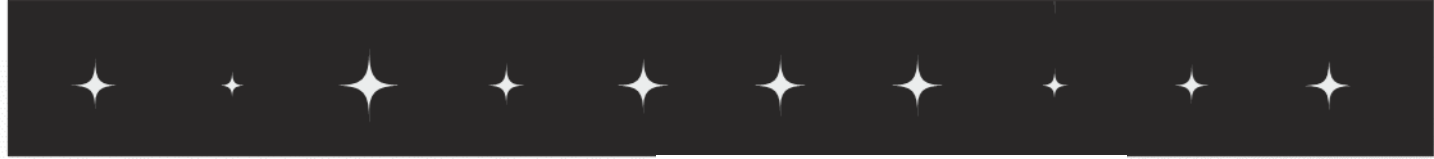


High-density peaks in the galaxy distribution (supercluster high-density cores) form in a very early Universe.

$z = 0, 1, 5, 10$, simulations by Einasto and Suhhonenko (2011)



The sizes of the largest bound structures in the Universe:
 Central parts of the supercluster cores ($< 10 \text{ Mpc h}^{-1}$)?
 Full high-density cores ($30 - 60 \text{ Mpc h}^{-1}$)?
 Full superclusters?



SCl2142 – supercluster with the high-density, collapsing core and 50 Mpc/h straight main body. Orientation of supercluster axis coincides with the orientations of the main cluster A2142, its X-rand and radio halo, and the brightest galaxy.



?

SGW and BGW – too big for this Universe?



Park et al. (2012) – large superclusters found also in simulations.

Supercluster complexes?

Einasto et al. (2006) – the fraction of observed very luminous superclusters is higher than in simulations

Sheth and Diaferio (2012) – tension with Gaussian initial conditions if the Sloan Great Wall is not the only great wall in the Universe

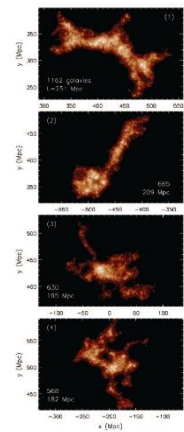
Morphology not recovered in simulations?

Too elongated?

BGW superclusters: the shape parameter < 0.2

Local rich superclusters: the shape parameter > 0.25

Einasto et al. (2007, 2011), Lietzen et al. (2016)





BGW in detail

Collapsing cores of a large set of superclusters:

dynamically evolving environments to study and test the structure, dynamics, and evolution of superclusters and their group, filament, and galaxy content and evolution.

The properties of galaxies and groups in walls and outside?

감사합니다

Thank you!

References:

Lietzen et al. 2016, A&A, 588, L4

Einasto et al. 2016, A&A, in press (1608.04988)

Gramann et al. 2015, A&A, 581, A135

Liivamägi et al. 2012, A&A 539, A80

Tempel et al. 2014, A&A 566, A1