Supercluster of galaxies in the Lambda significance diagram

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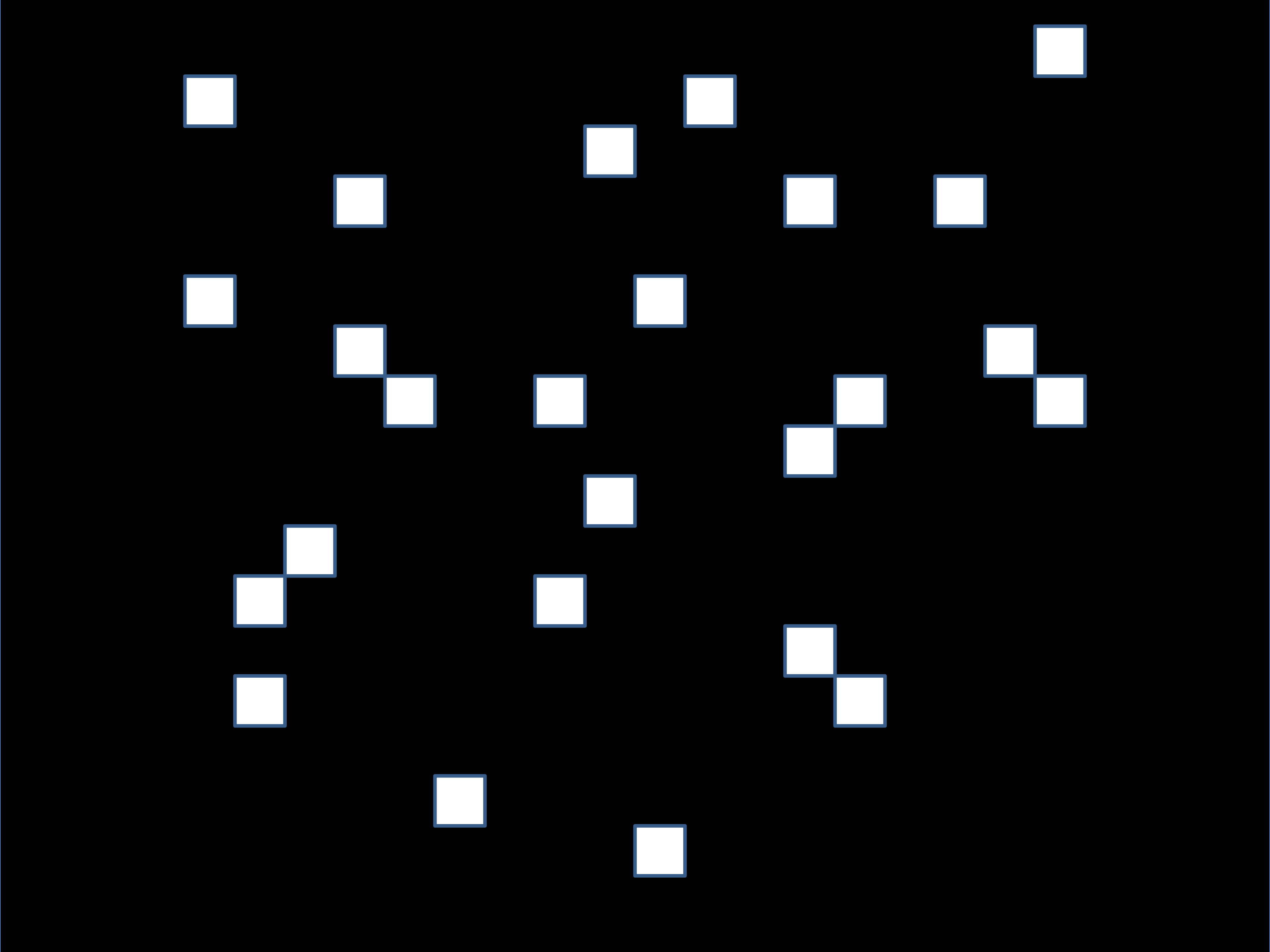
Teerikorpi et al. 2015, Gramann et al. 2015, Einasto, M., et al . 2015

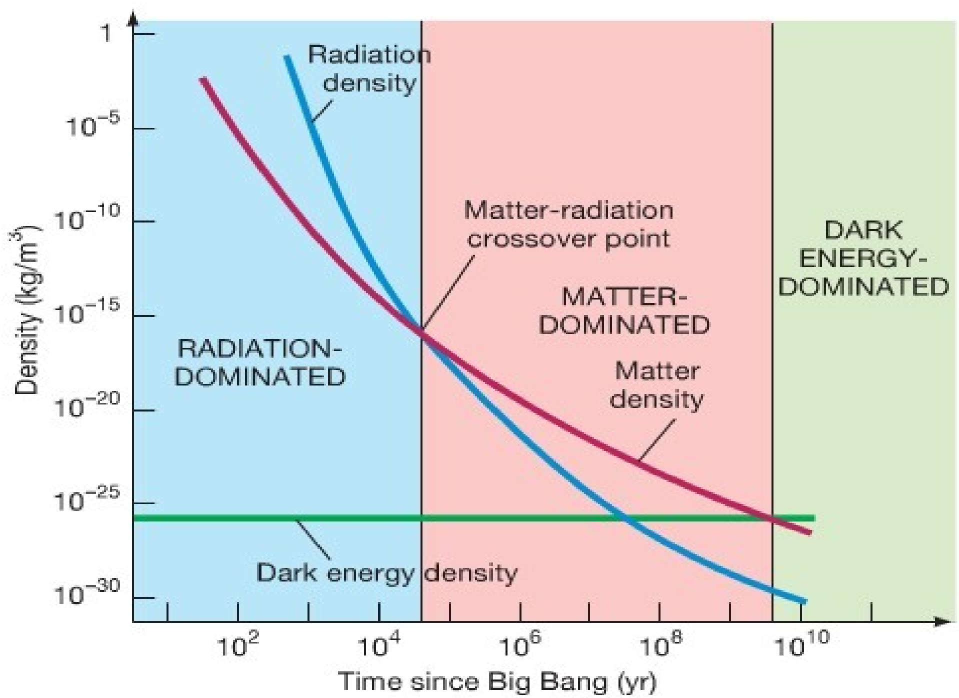


Global density (Planck) of the DE is about
$\rho_\Lambda = 6 \times 10^{-30}$ gcm^{-3} → low but dominate because uniform across space
(critical density $\rho_{crit} = 8.52 \times 10^{-30}$ gcm^{-3})

In standard ΛCDM, DE is repulisve force → Antigravity→ accelerating expansion

In the regions where DE dominates over the gravitating matter structures do not grow

Since z=0.7 the formation of the structures are slowed down



At the present epoch largest bound systems are just forming → in the future they will not be necessary bound anymore

For spherically symmetric system :
The force affecting a test particle with mass *m* as the sum of Newton's gravity force produce by a mass M and Einstein's antigravity force due to DE

$$F(R) = \left(-\frac{GM}{R^2} + \frac{8\pi G}{3}\rho_\Lambda R\right) m = \frac{4\,\pi}{3}\,GR\,(-\rho + 2\,\rho_\Lambda)\,m.$$

(Chernin et al. 2009)

Gravity and antigravity equal when $\rho=2\rho_\Lambda$

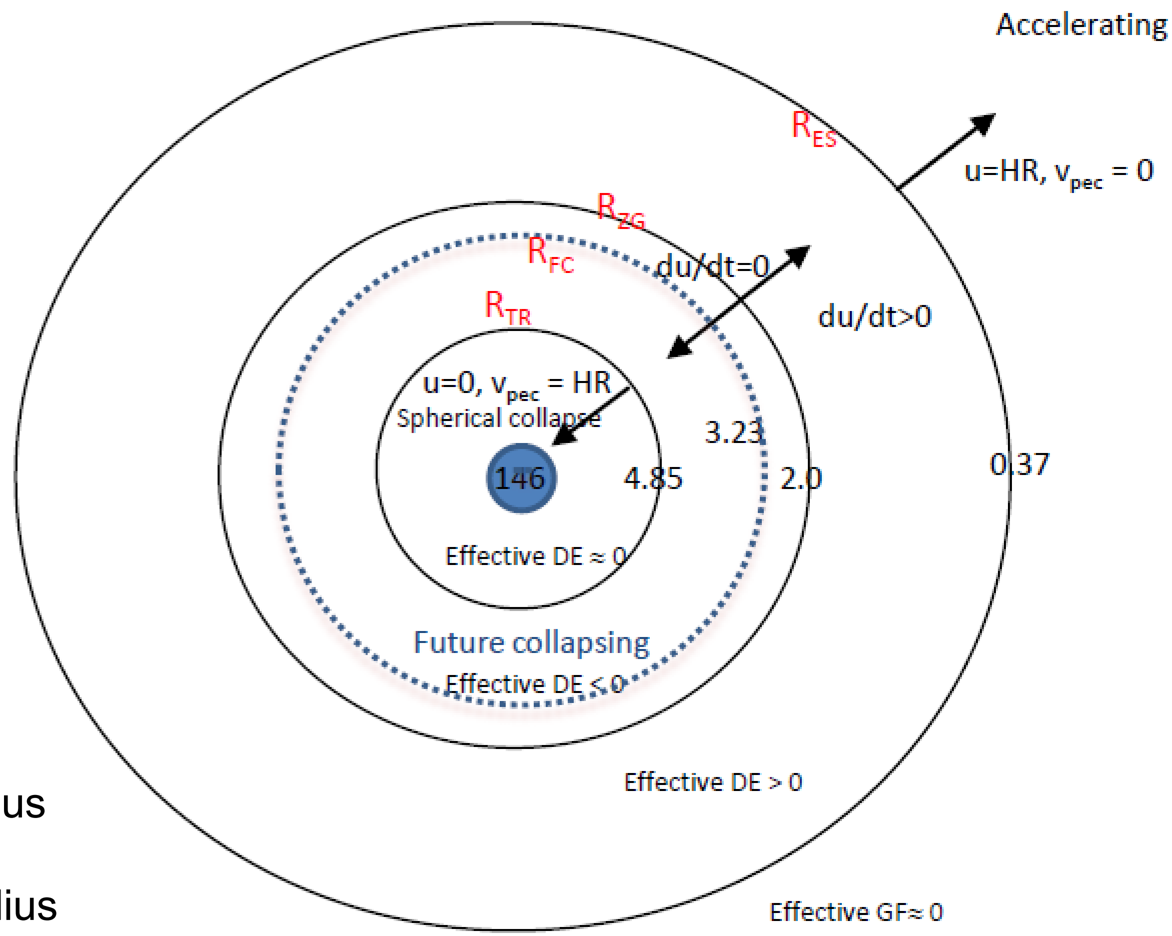
In this case the acceleration around the system is zero : Zero gravity radius R_{ZG}

Schematic graph of the interplay between the dark energy and the gravitational force for the spherical system with fixed mass. Different radii bound the regions according the dominant component. Physical coordinates.

ρ/ρ_Λ in different regions

$u=HR-v_{pec}$

R_{ZG} =gravitationally bound at the present epoch



Dynamically different regions:

R_{TR} = turn around radius
R_{FC} = future collapse radius
R_{zG} = zero gravity radius
R_{ES} = Einstein-Straus radius

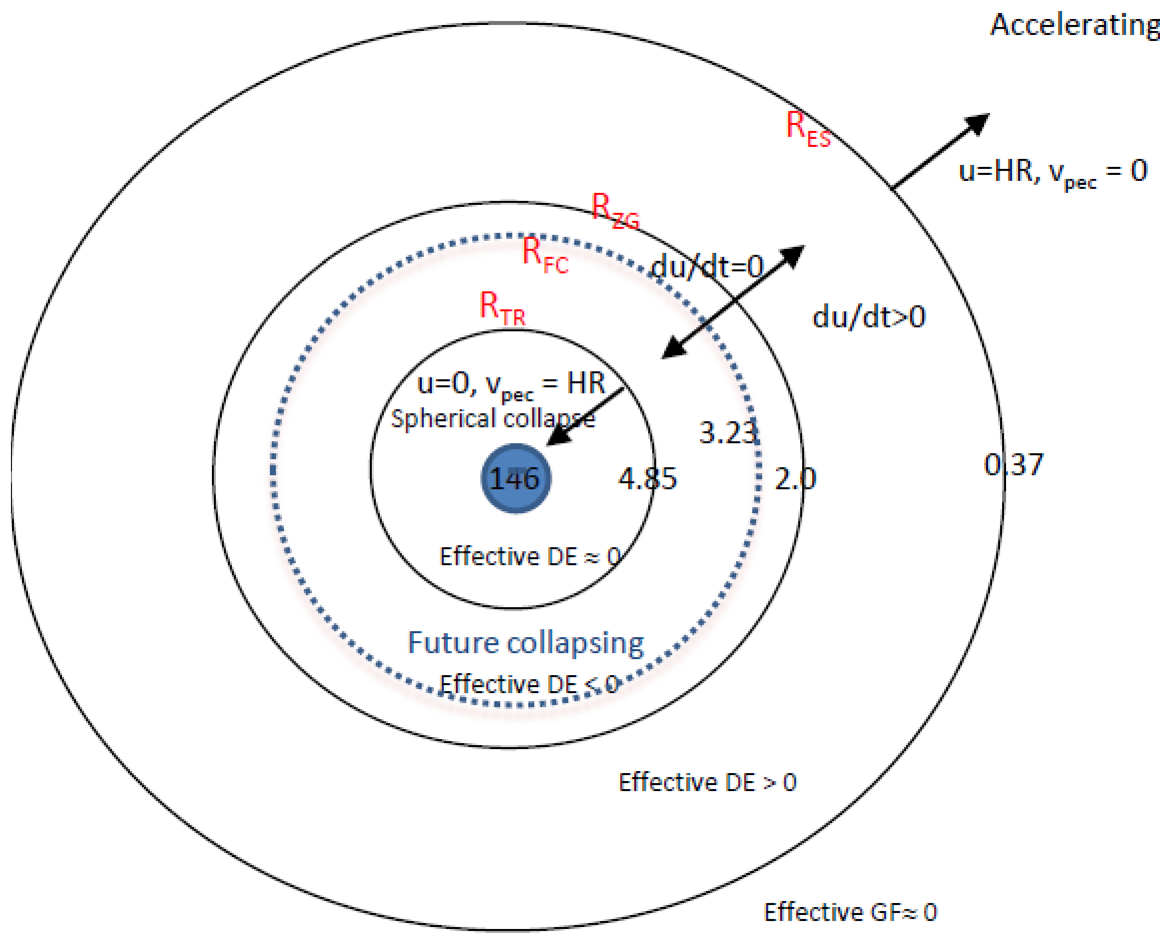
ρ/ρ_Λ in different regions

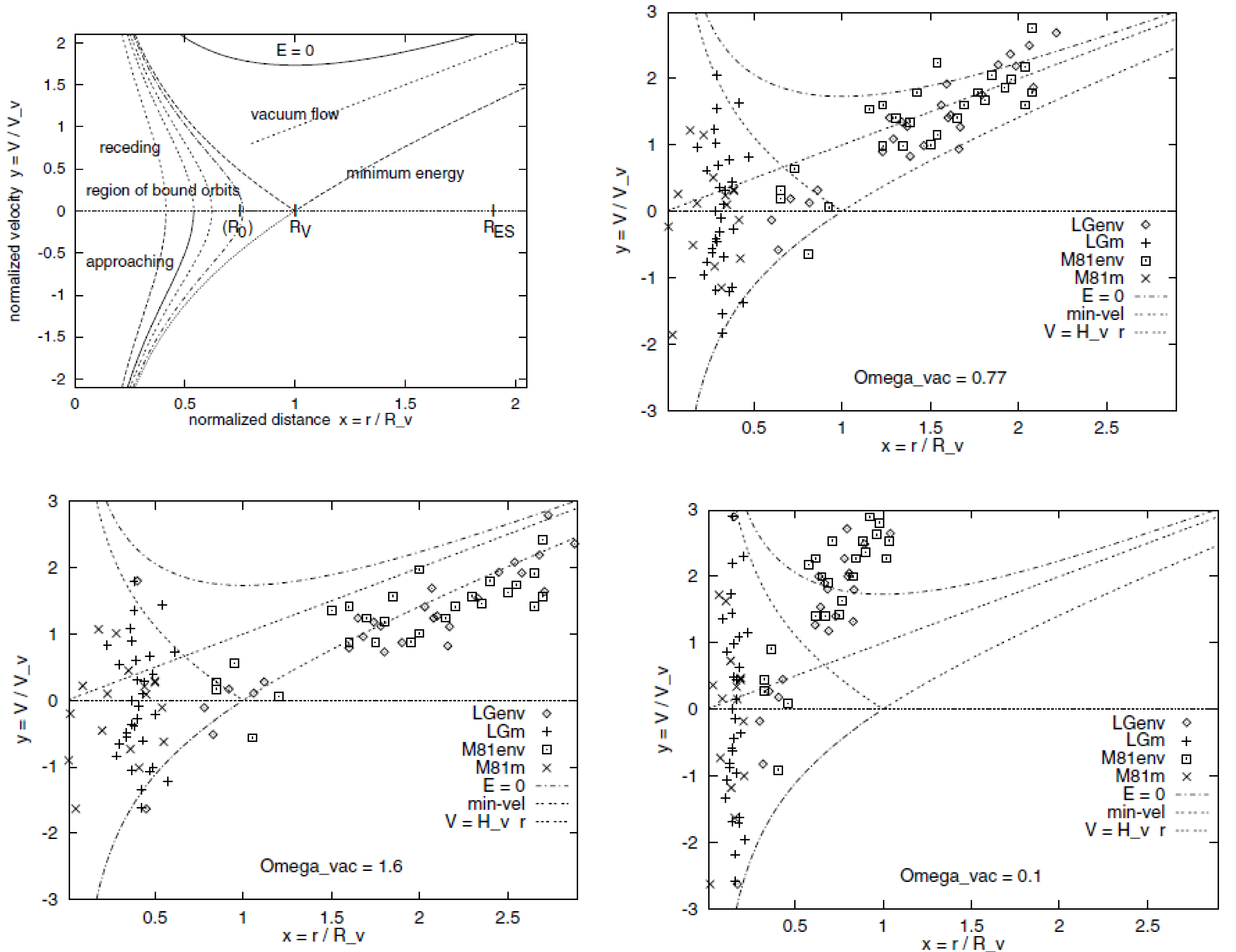
$u = HR - v_{pec}$

R_{ZG} =gravitationally bound at the present

(1) Ω_m	(2) ρ/ρ_m	(3) ρ/ρ_Λ	(4) ρ/ρ_{crit}
Virial			
1.0	178	-	178
0.3	340	146	102
0.27	360	133	97
Turn-around			
1.0	5.55	-	5.55
0.3	12.2	5.21	3.65
0.27	13.1	4.85	3.54
Future collapse			
0.3	7.86	3.37	2.36
0.27	8.73	3.23	2.36
Zero gravity			
0.3	4.67	2.0	1.40
0.27	5.41	2.0	1.46
Linear			
0.3	1.0	0.43	0.3
0.27	1.0	0.37	0.27

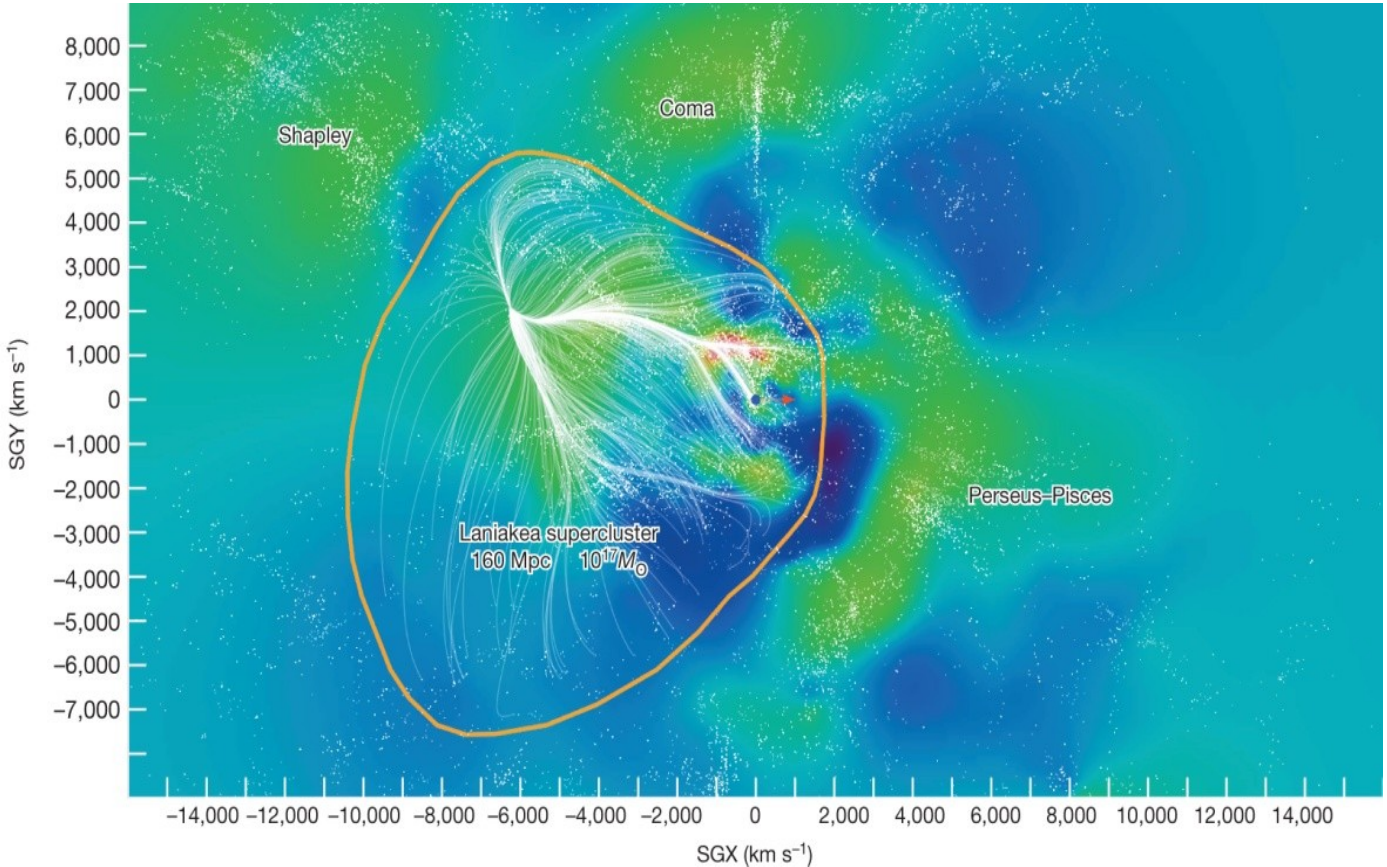
Gramann et al. 2015





Teerikorpi et al. 2008

The Laniakea supercluster (Tully et al. 2014) is not far from the E-S distance as calculated from its mass 10^{17} M_{sun}.



Tully et al. 2014 Nature 513, 71

The usefull parameter that characterizes the influence of the DE energy density ratio $<\rho_M>/\rho_\Lambda$ as calculated for the system under inspection (Teerikorpi et al. 2015).

$$\log\langle\rho_{\mathrm{M}}\rangle/\rho_{\Lambda} = 0.43 + \log M/10^{12}M_{\odot} - 3 \times \log R/\mathrm{Mpc}.$$

Lambda significance diagram

Graph of the dark energy influence (Teerikorpi et al. 2015)

(Teerikorpi et al. 2015) :
the influence of DE for the system under inspection

Different regions in such graph corresponding to the mass and size of a system and its dynamical state

Location in the diagram indicates whether is overall dynamics is dominated by gravity or DE antigravity

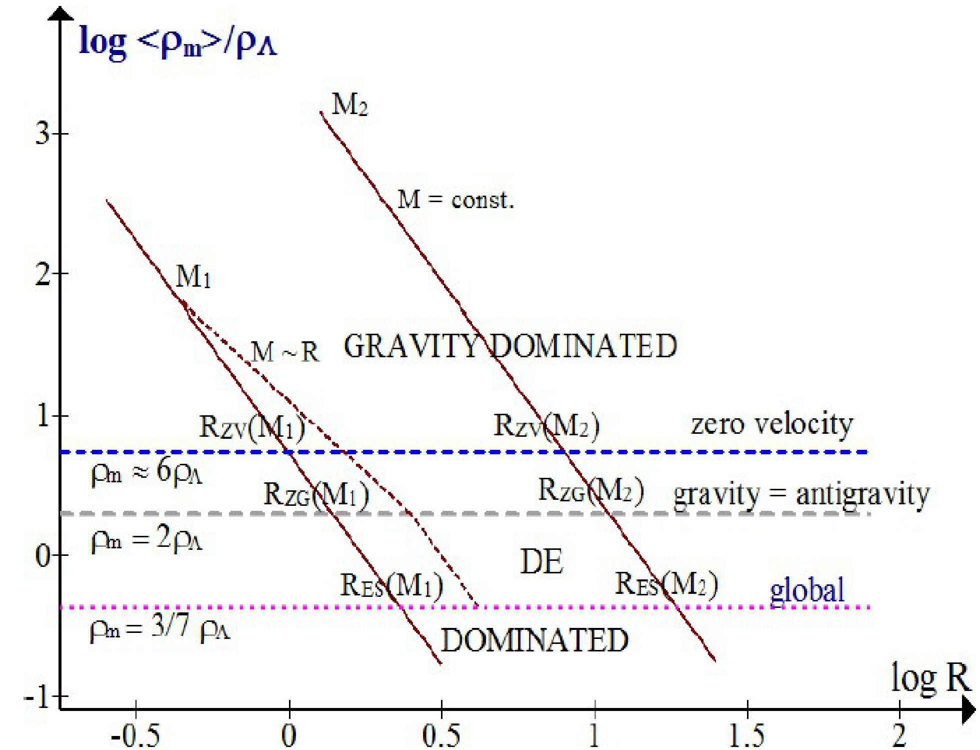
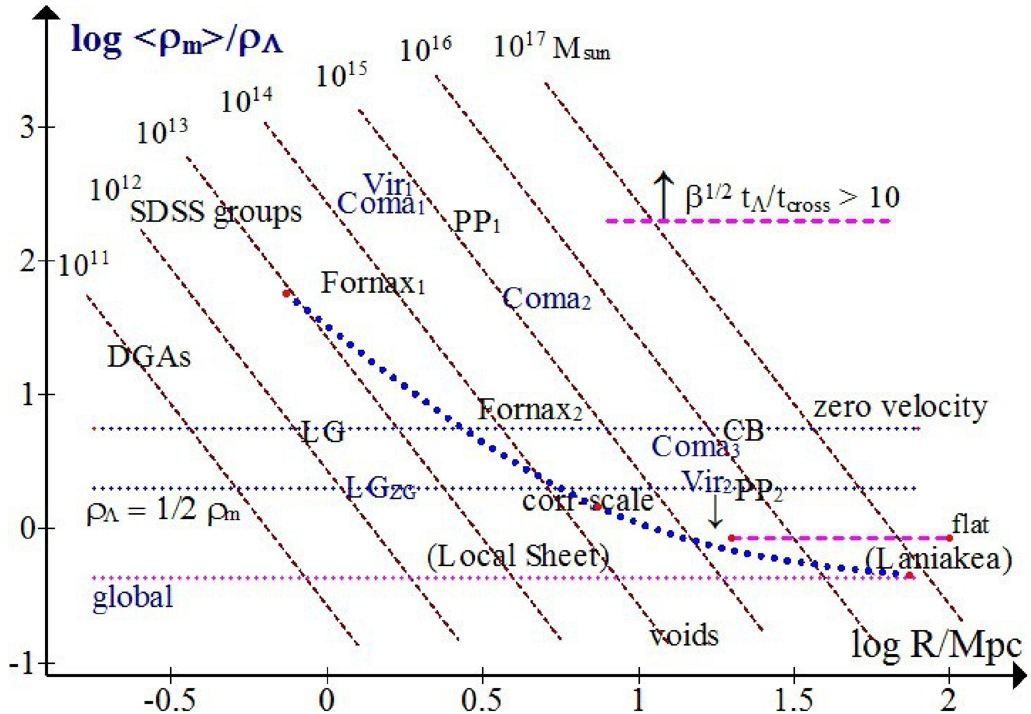


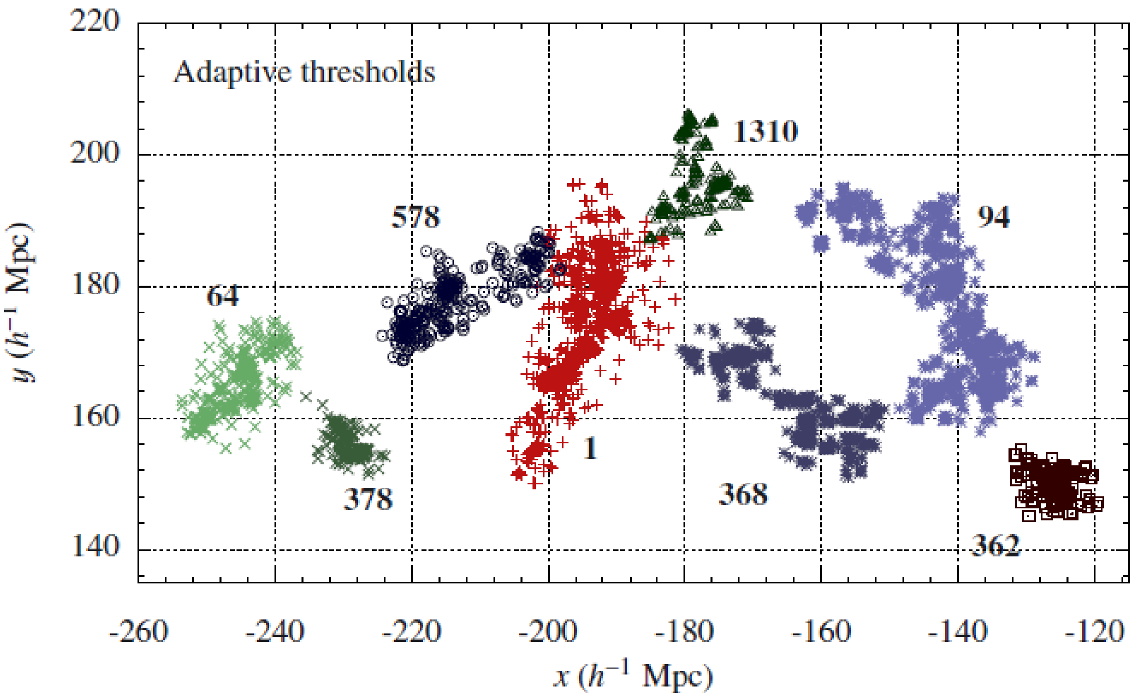
Fig. 1. $\log\langle\rho_M\rangle/\rho_\Lambda$ vs. $\log R$ for spherical systems. The inclined lines correspond to different mass values. Above the "gravity = antigravity" line, the region is dynamically dominated by gravitation, and below this line by DE. Intersections give the radii R_{ZV}, R_{ZG}, and R_{ES}. Dotted inclined lines illustrate the case where the mass increases with the radius (see the text).

$$\log\langle\rho_M\rangle/\rho_\Lambda = 0.43 + \log M/10^{12}M_\odot - 3 \times \log R/\mathrm{Mpc}.$$

Example for galaxy systems:

Different mass estimations





- Observations:
- Superclusters of galaxies: SDSS DR7 (Liivamägi et al. 2012), 1313 superclusters, adaptive
- Simulations:
- Millenium simulations 1214 superclusters (Liivamägi et al. 2012)

Superclusters A2142

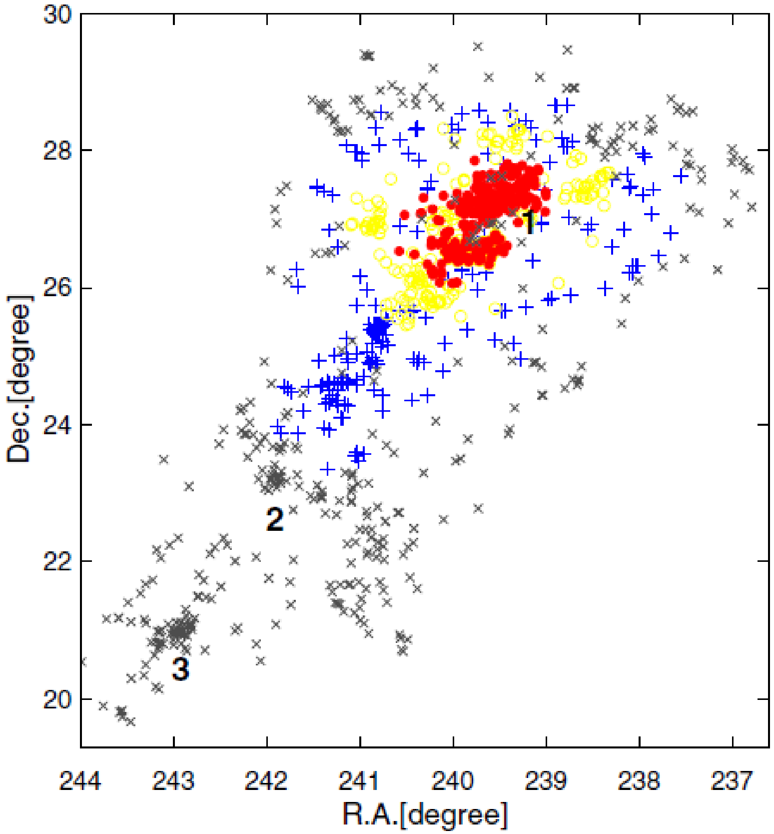


Fig. 1. Distribution of galaxies in the A2142 supercluster in the sky plane in global density regions as described in the text. Red filled circles denote galaxies in the region of global density $D8 \geq 17$; yellow empty circles correspond to galaxies with global density $13 \leq D8 < 17$; Blue crosses correspond to galaxies with global density $8 \leq D8 < 13$; and grey Xs galaxies with $5 \leq D8 < 8$. The size of the highest density region is approximately 1.8 degrees, and the size of the region with $D8 \geq 13$ is approximately 3 degrees; sizes in megaparsecs are given in Table 2. Number 1 marks the Abell cluster A2142, and numbers 2 and 3 indicate two regions of galaxy groups in the tail of the supercluster, as explained in the text.

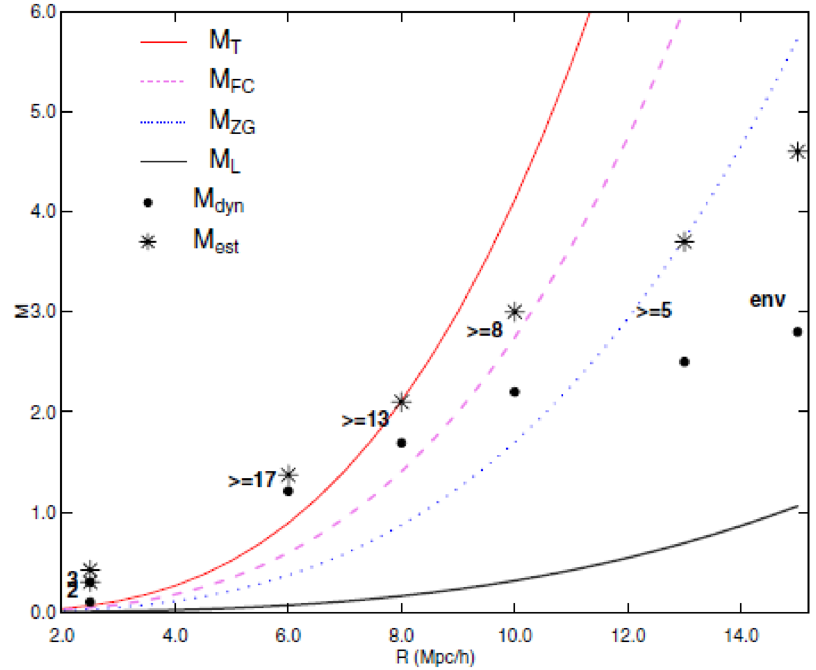
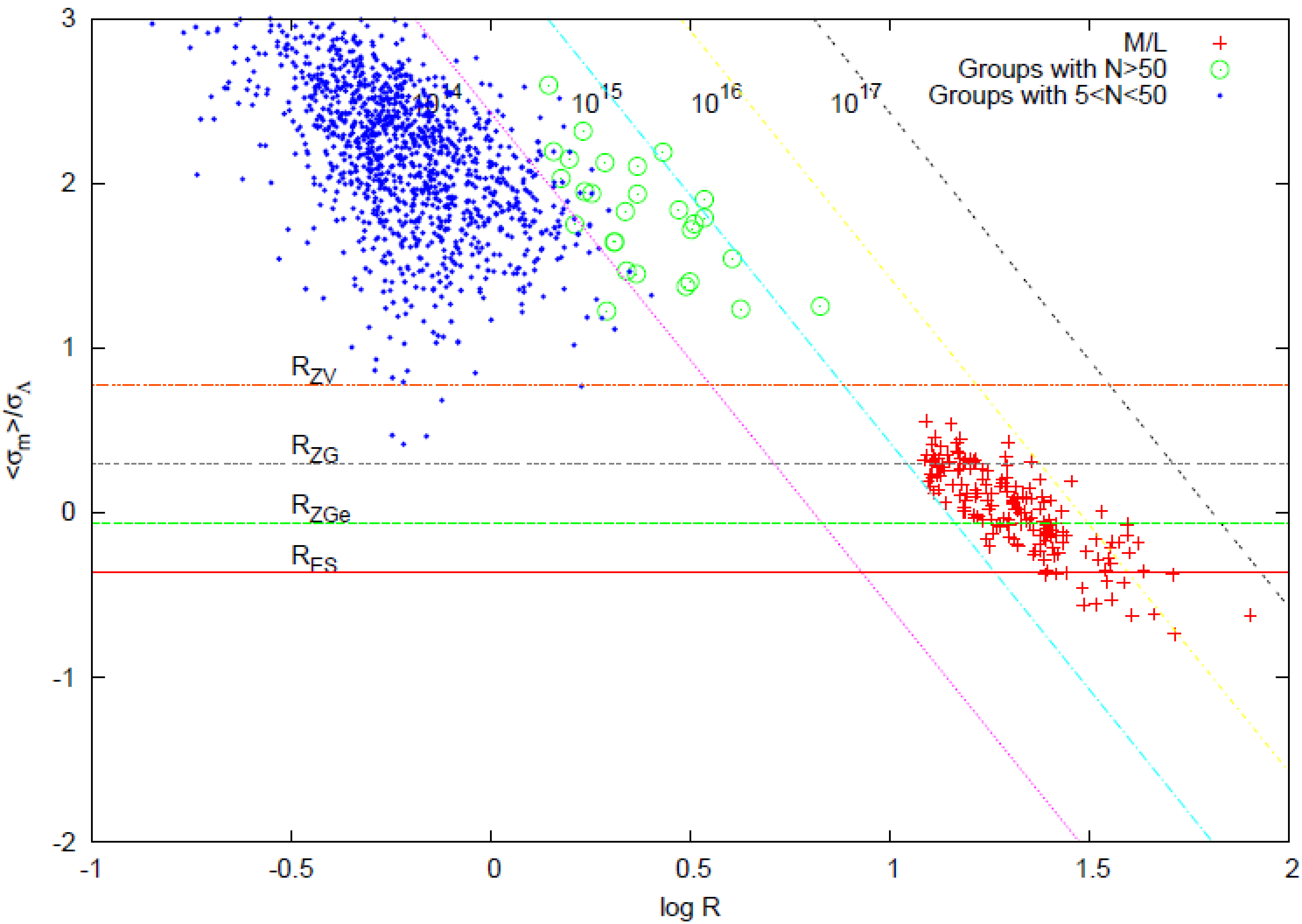
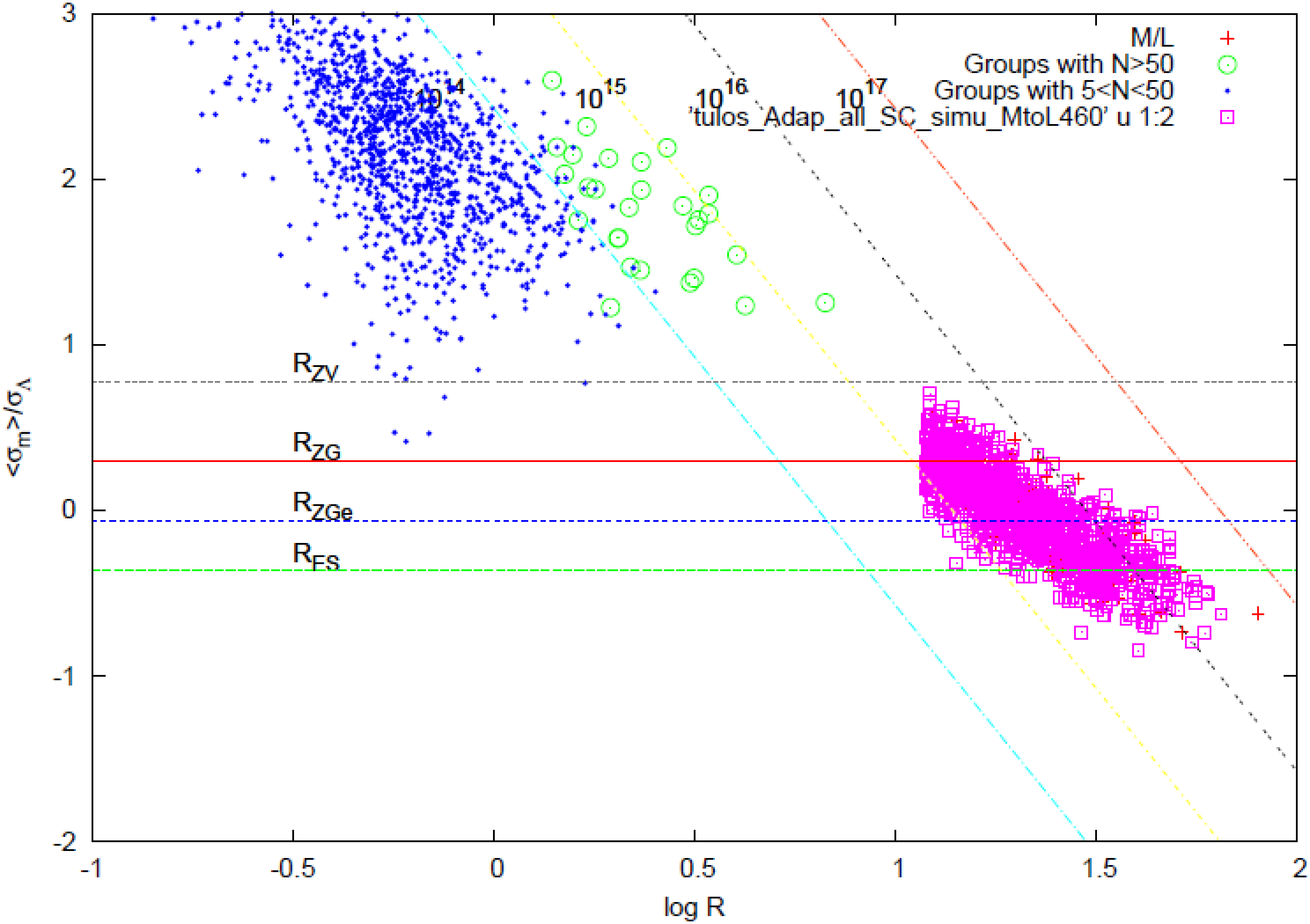


Fig. 2. Mass corresponding to the turnaround mass $M_T(R)$ (red line), future collapse mass $M_{FC}(R)$ (violet line), zero-gravity mass $M_{ZG}(R)$ (blue line), and linear mass $M_L(R)$ (grey line; in units of $10^{15}\ h^{-1}\ M_\odot$) versus radius of a sphere R in different dynamical evolution models for $\Omega_m = 0.27$. Filled circles show the total masses of galaxy groups in regions of different global density in the A2142 supercluster (Table 2). Stars denote estimated masses as explained in the text. Numbers show global density lower limit for a region (*env* marks Main+env region, 2 and 3 denote regions of galaxy groups in the tail of the supercluster).

Gramann et al. 2015



M/L
Groups with N>50
Groups with 5<N<50
10^{14}
10^{15}
10^{16}
10^{17}
R_{ZV}
R_{ZG}
R_{ZGe}
R_{FS}
$<\sigma_m>/\sigma_\Lambda$
log R
3
2
1
0
-1
-2
-1
-0.5
0
0.5
1
1.5
2


M/L
Groups with N>50
Groups with 5<N<50
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10^14
10^15
10^16
10^17
R_ZV
R_ZG
R_ZGe
R_FS
<σm>/σΛ
log R
3
2
1
0
-1
-2
-1
-0.5
0
0.5
1
1.5
2

Concluding remarks:

- Graph of dark energy significance can be use to characterize system of galaxies

- Different regions in the diagram correspond these systems dynamical state within the Λ dominated expanding universe

- The study of the galaxy properties in dynamically different regions may provide interesting insight for the environmental studies of the galaxies in superclusters.

- Definition of the superclusters

- Mass of the supercluster: M/L, lensing, dynamical mass

- Theory is for spherical systems → the spherical superclusters –> not typical.

- Redshift/real space – Kaiser effect

- Simulations