The Local Group in the Cosmic Web

in collaboration with
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arXiv: 1408.3166

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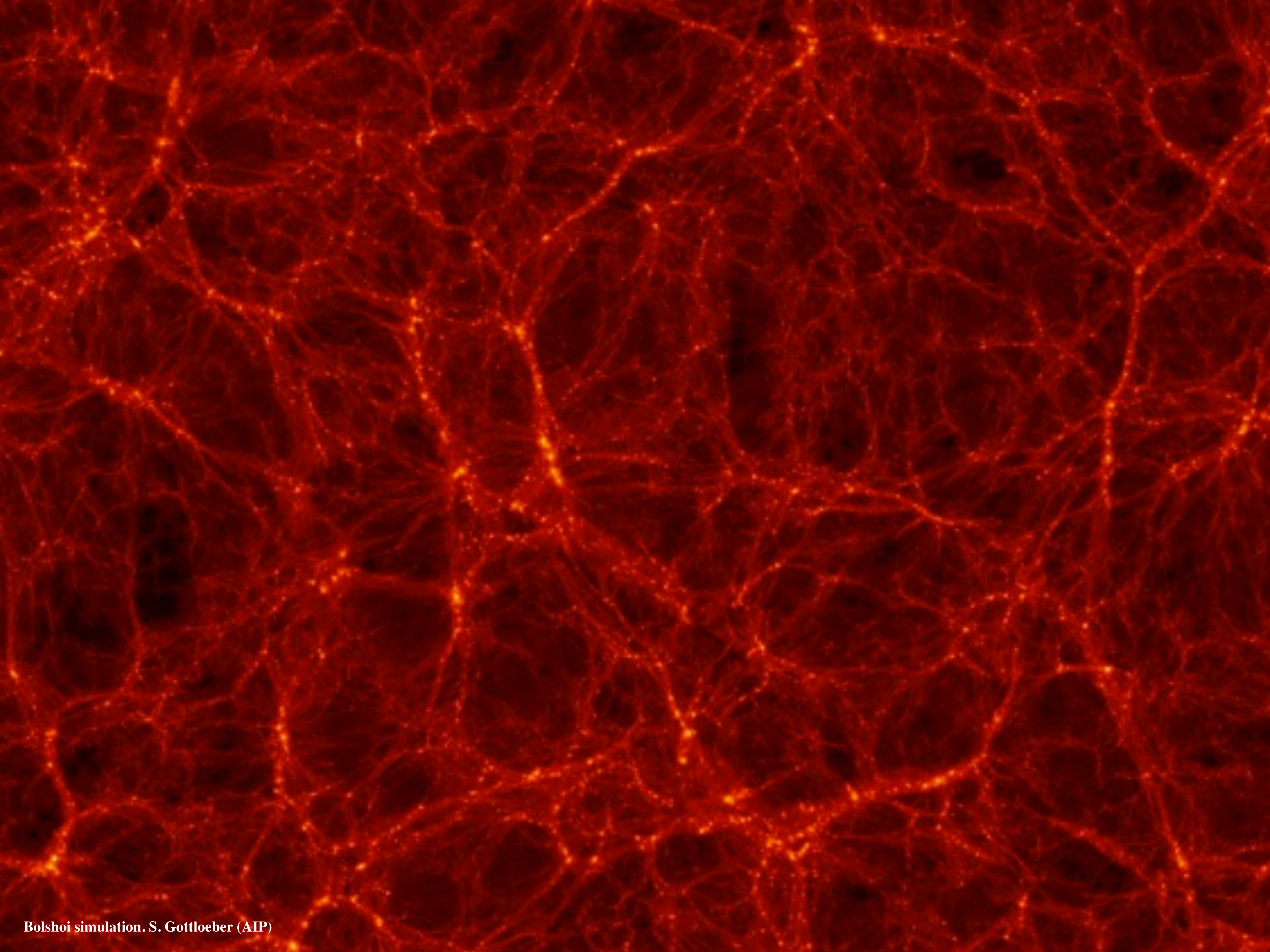
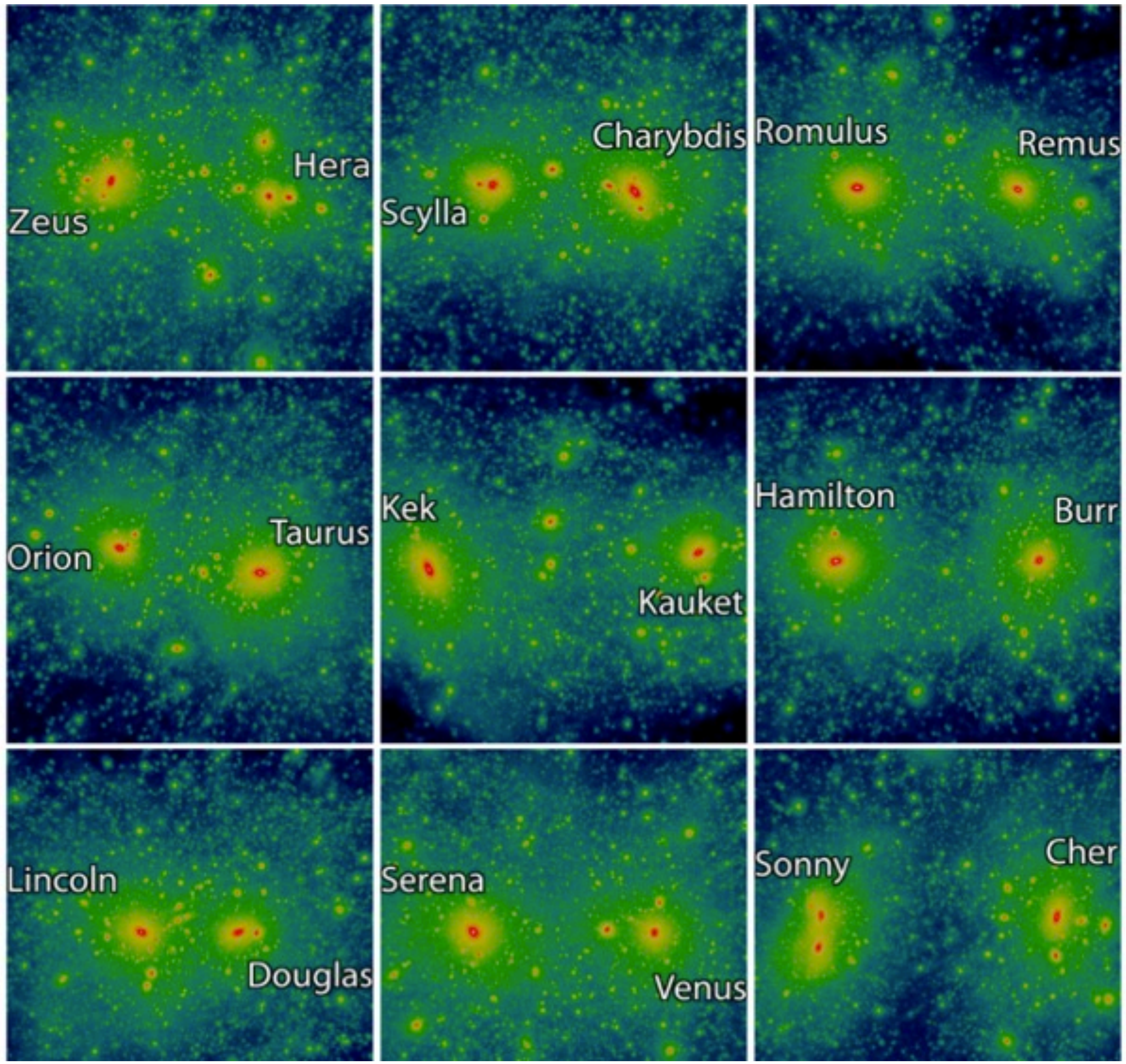
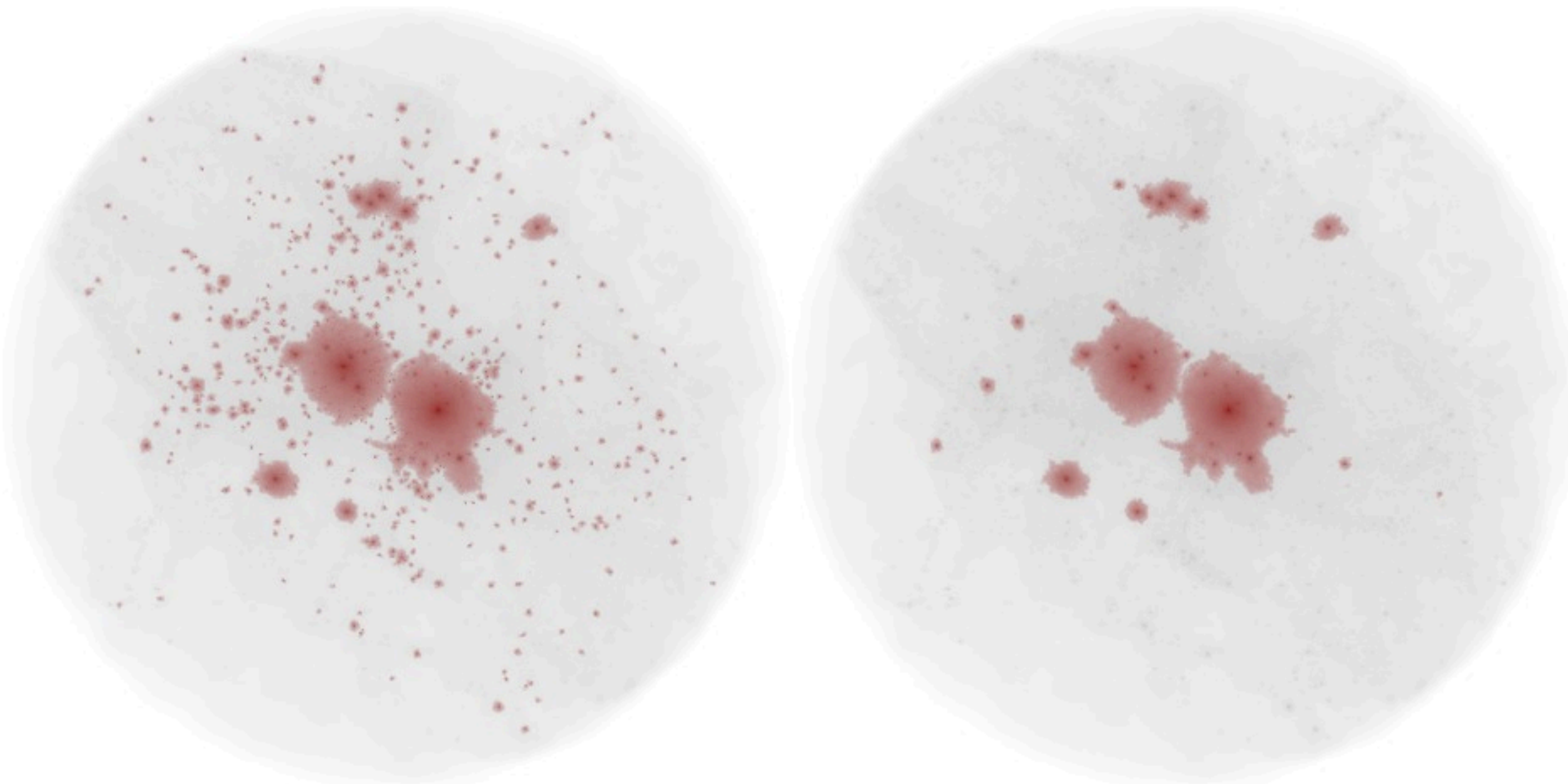

Bolshoi simulation. S. Gottloeber (AIP)

Pairs as the natural way to think about the MW



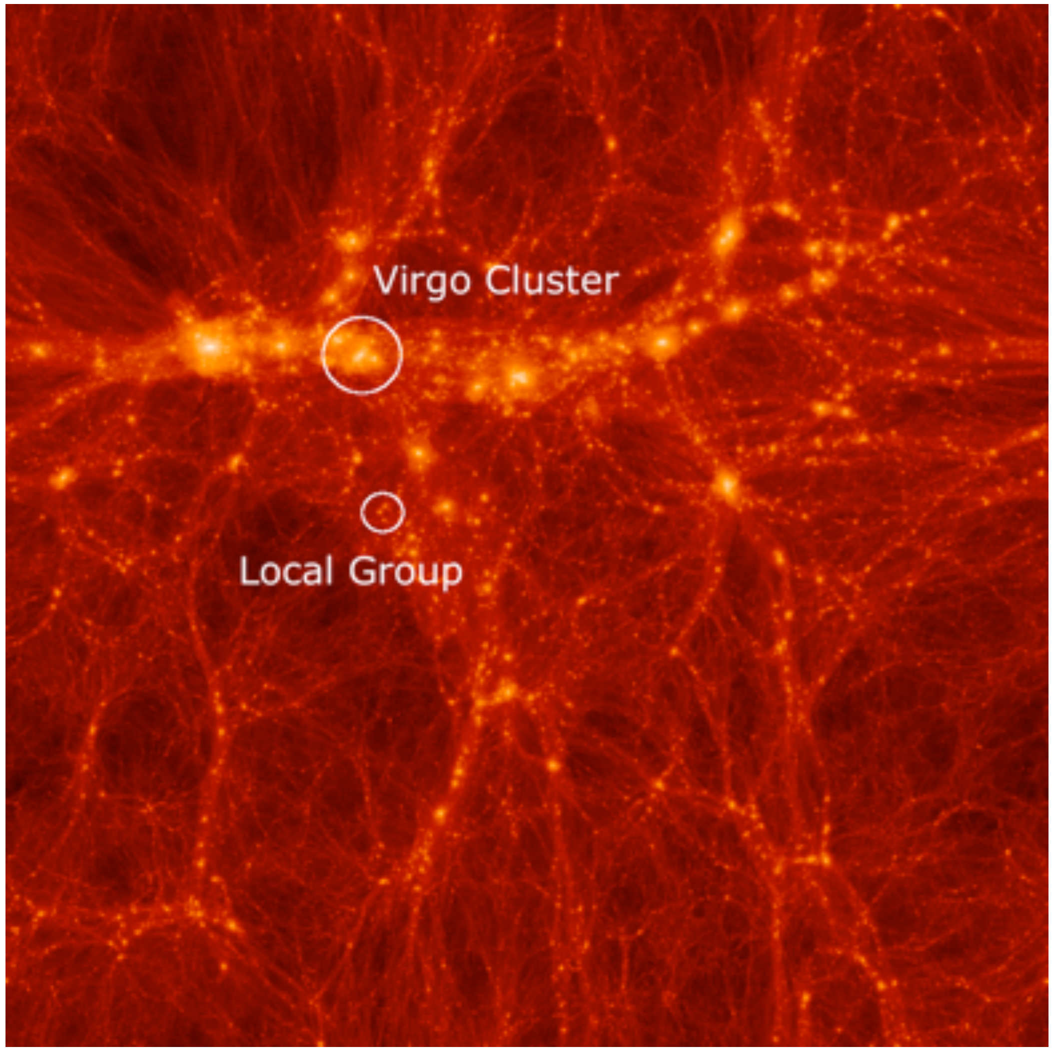
ELVIS, Garrison-Kimmel et al., 2014

Pairs as the natural way to think about the MW



DOVE, Sawala et al., 2014

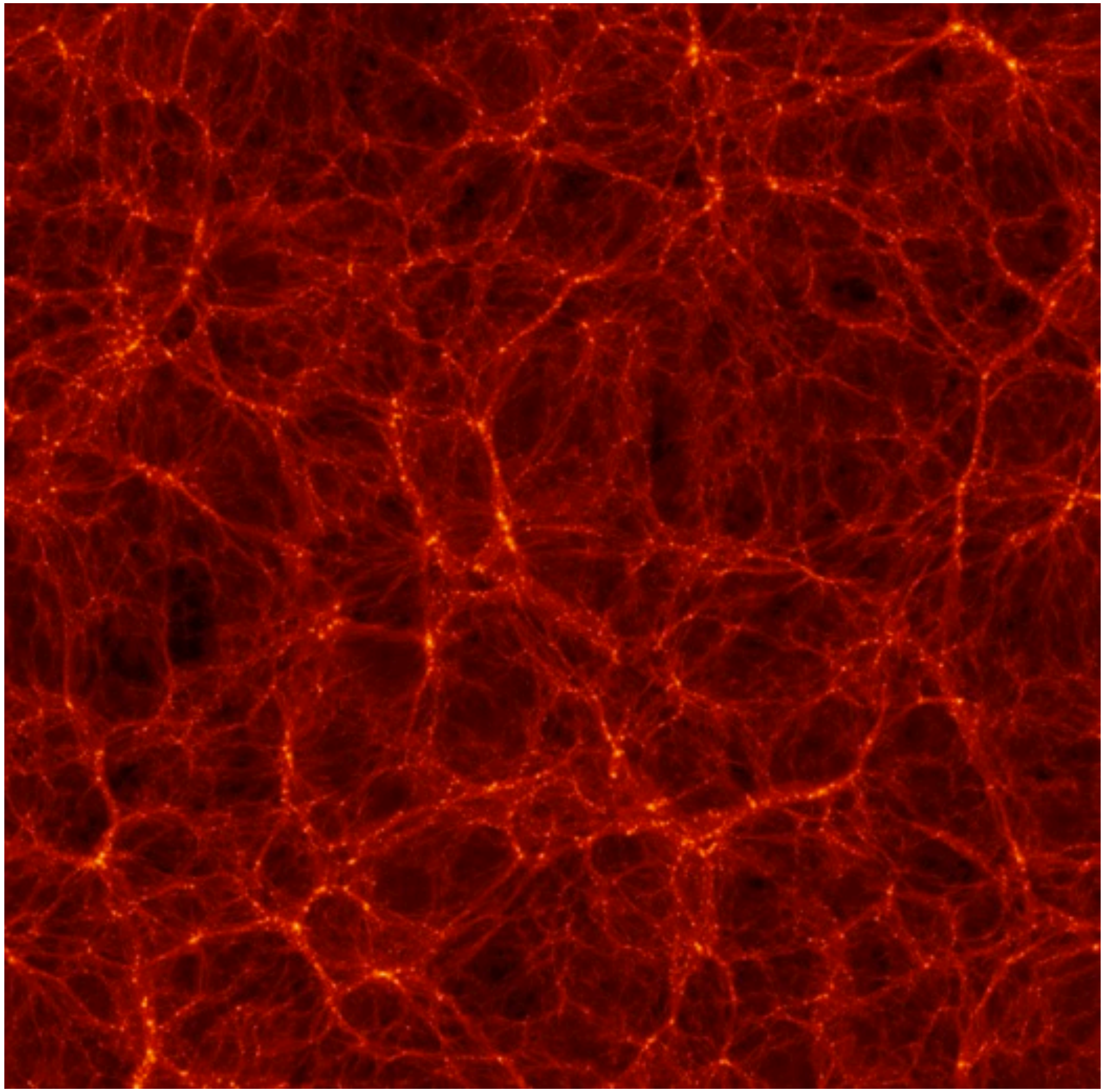
CLUES also considers the pairs in its large-scale environment



Gottloeber, Hoffman, Yepes 1005.2687

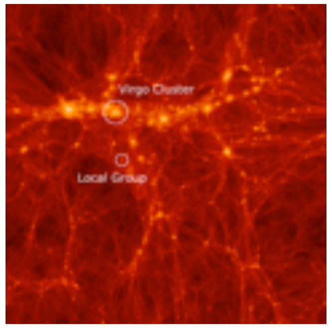
- Large Scales (5-7 Mpc) are fixed
- Small scales are random.
- 200 low resolution realizations until a LG is found.

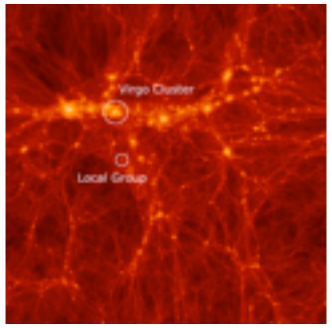
Constrained simulations must be compared against random realizations

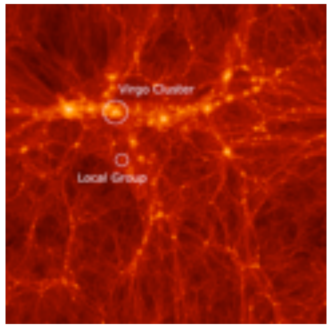


BOLSHOI

CLUES



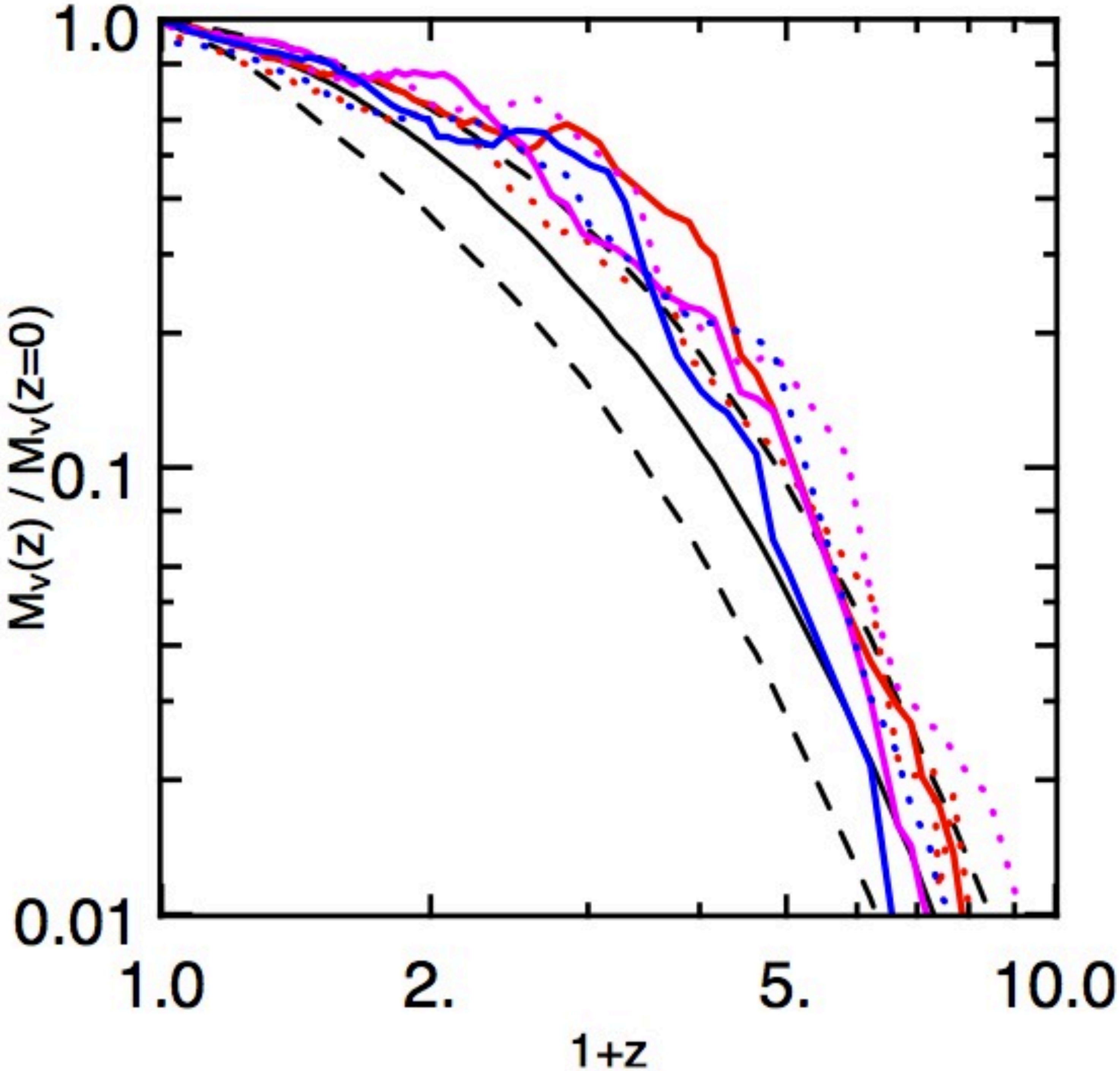




We consider 5 conditions to define a LG in a unconstrained simulation

- Individual halo mass
- Halo separation
- Negative radial velocity
- Isolated (3Mpc)
- Isolated (7Mpc) (>5 10^{13} M_{sol})

The LGs in constrained simulations assemble earlier



JEF-R, Hoffman, Yepes, Gottloeber, Piontek, Klypin, Steinmetz, MNRAS 2011, 1107.0017

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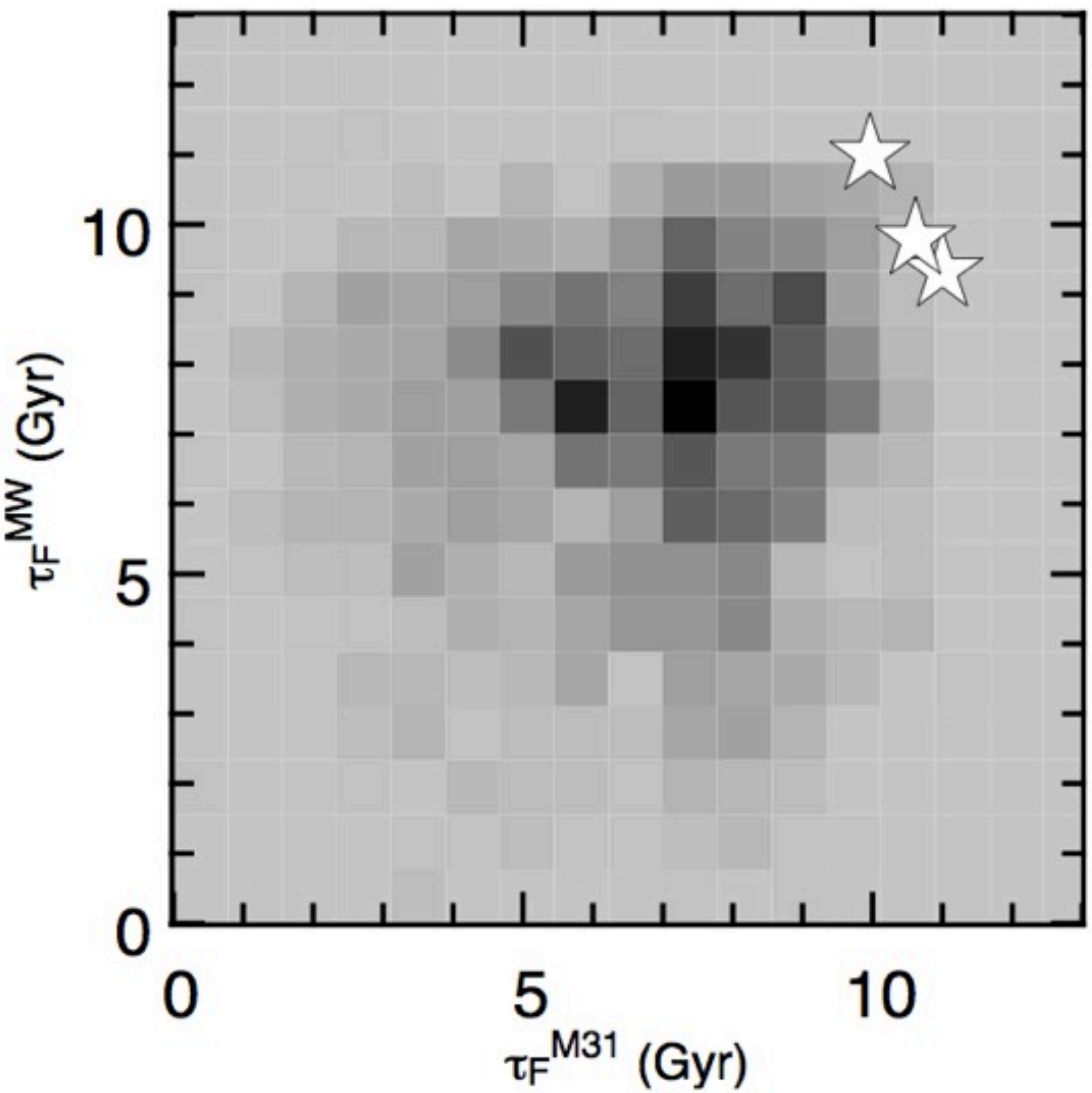
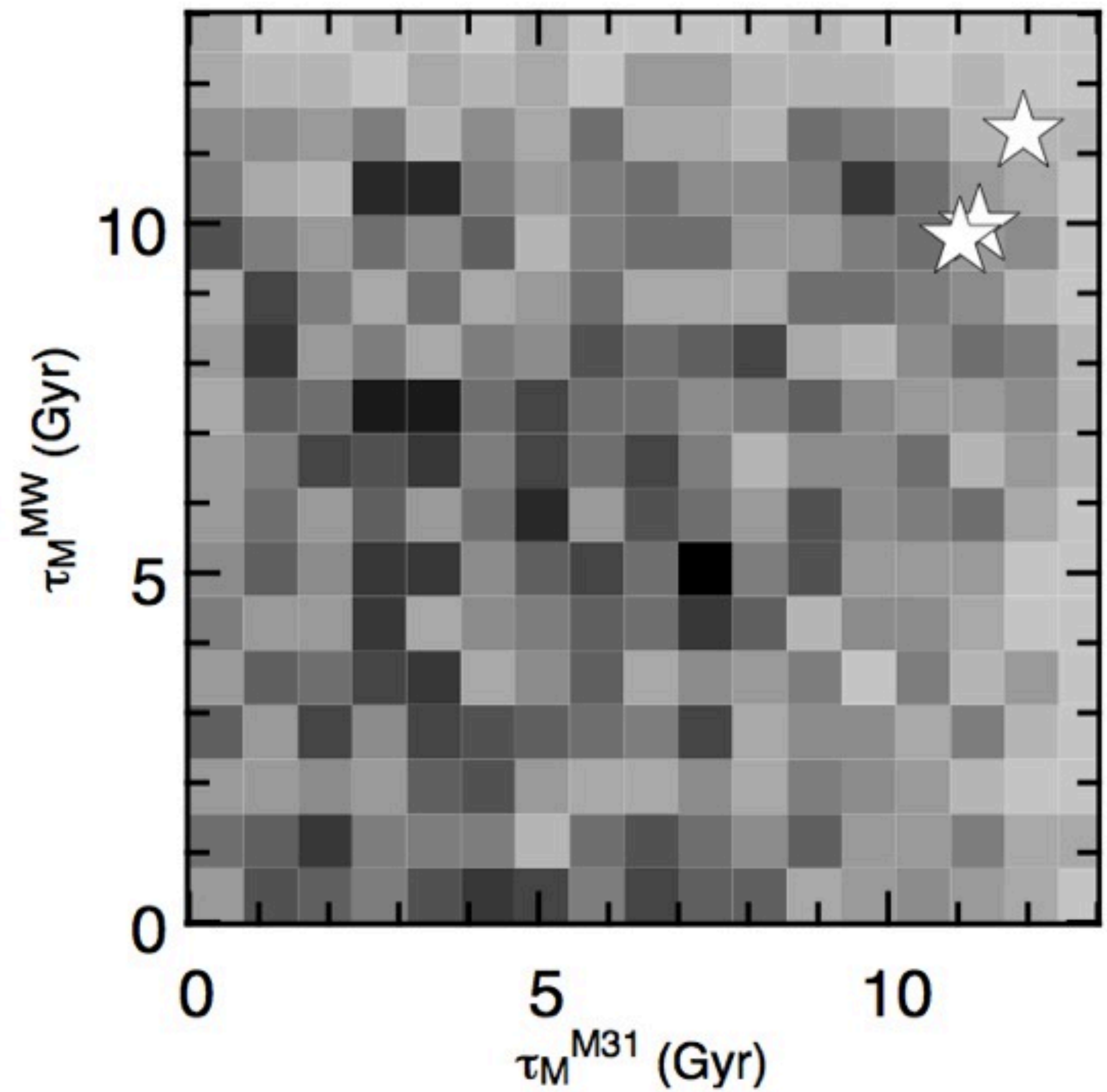


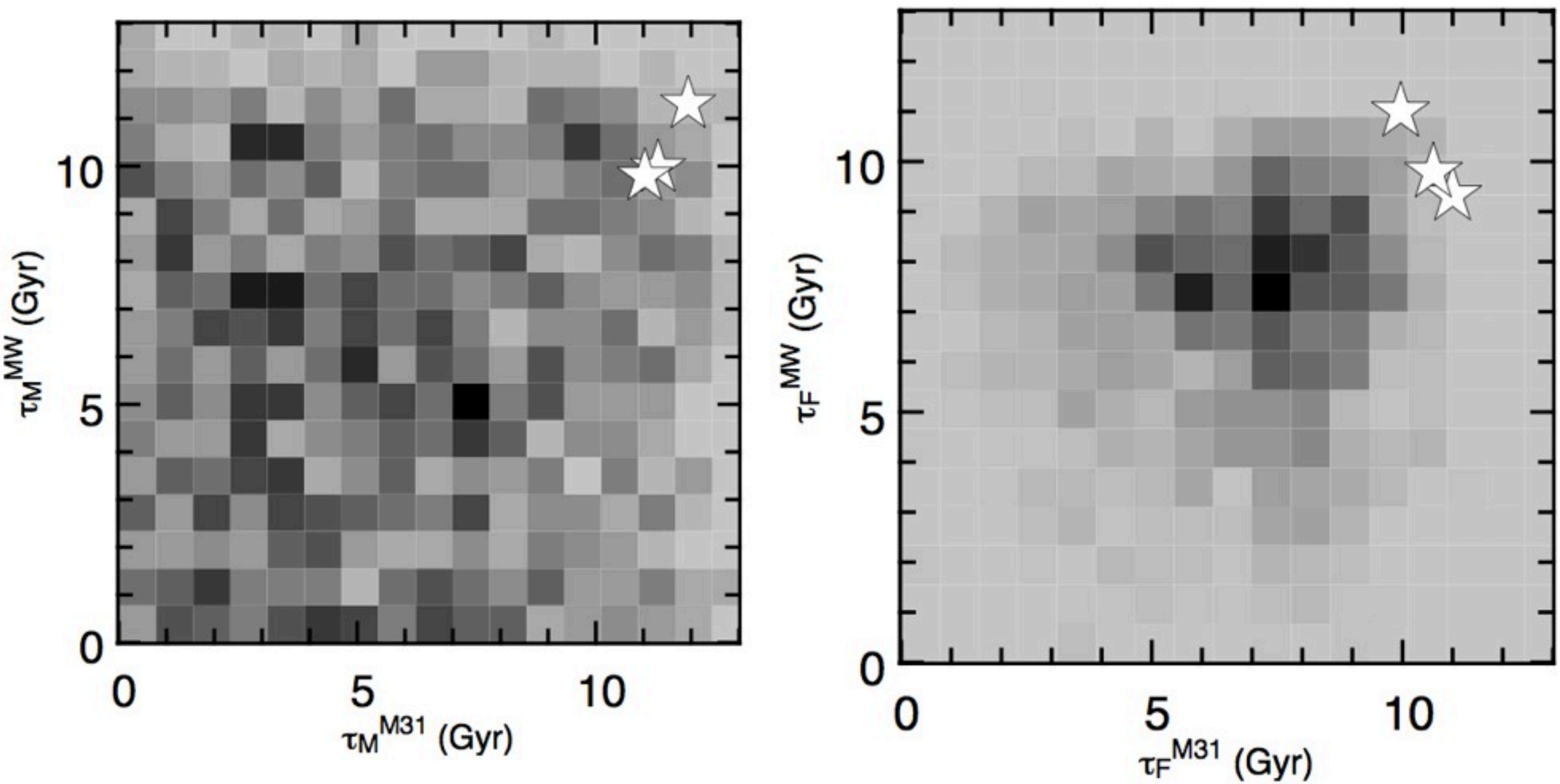
JEF-R, Hoffman, Yepes, Gottloeber, Piontek, Klypin, Steinmetz, MNRAS 2011, 1107.0017

The LGs in constrained simulations live quietly



JEF-R, Hoffman, Yepes, Gottloeber, Piontek, Klypin, Steinmetz, MNRAS 2011, 1107.0017

The LGs in constrained simulations are not common when compared against a random sample



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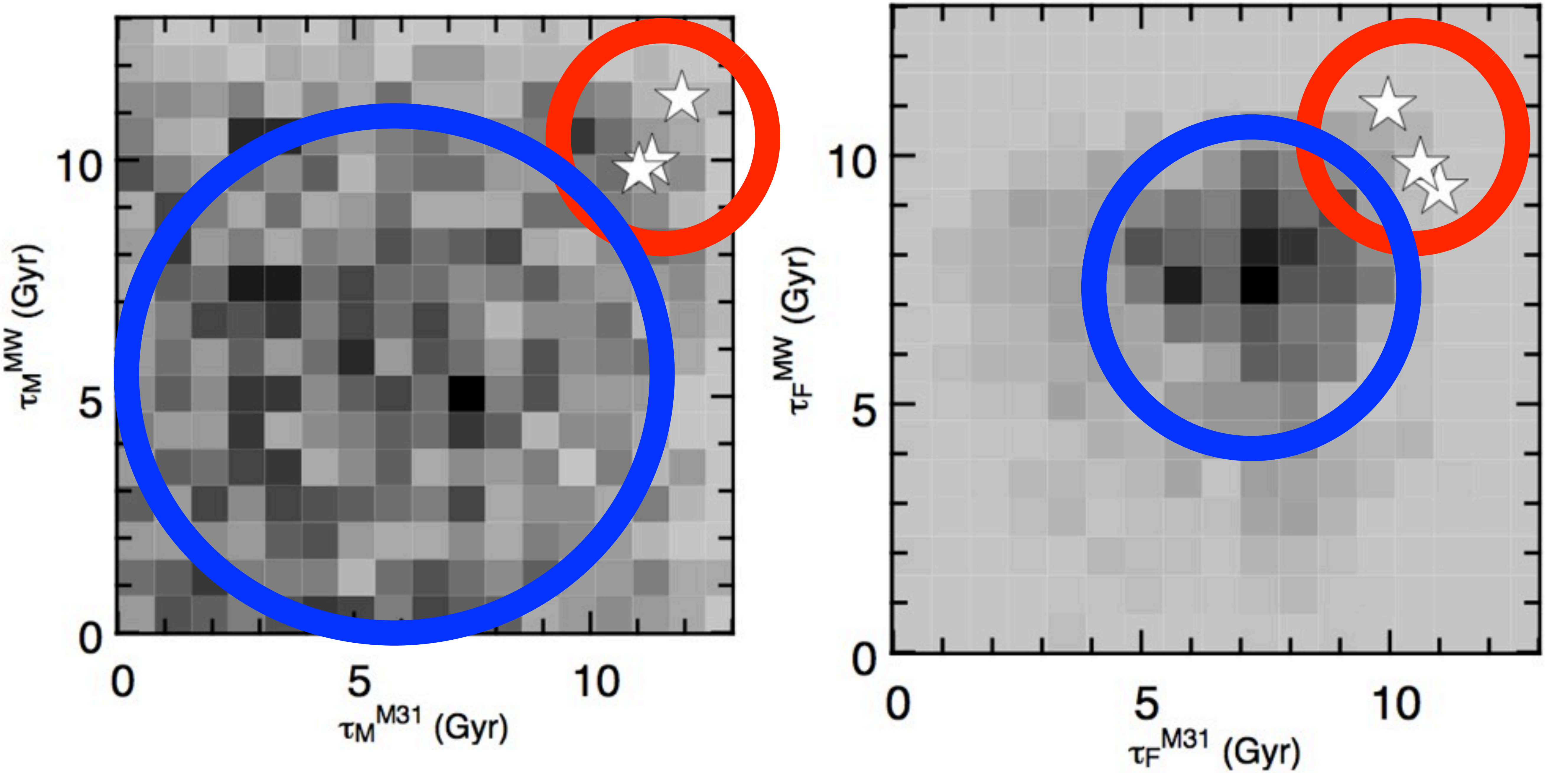
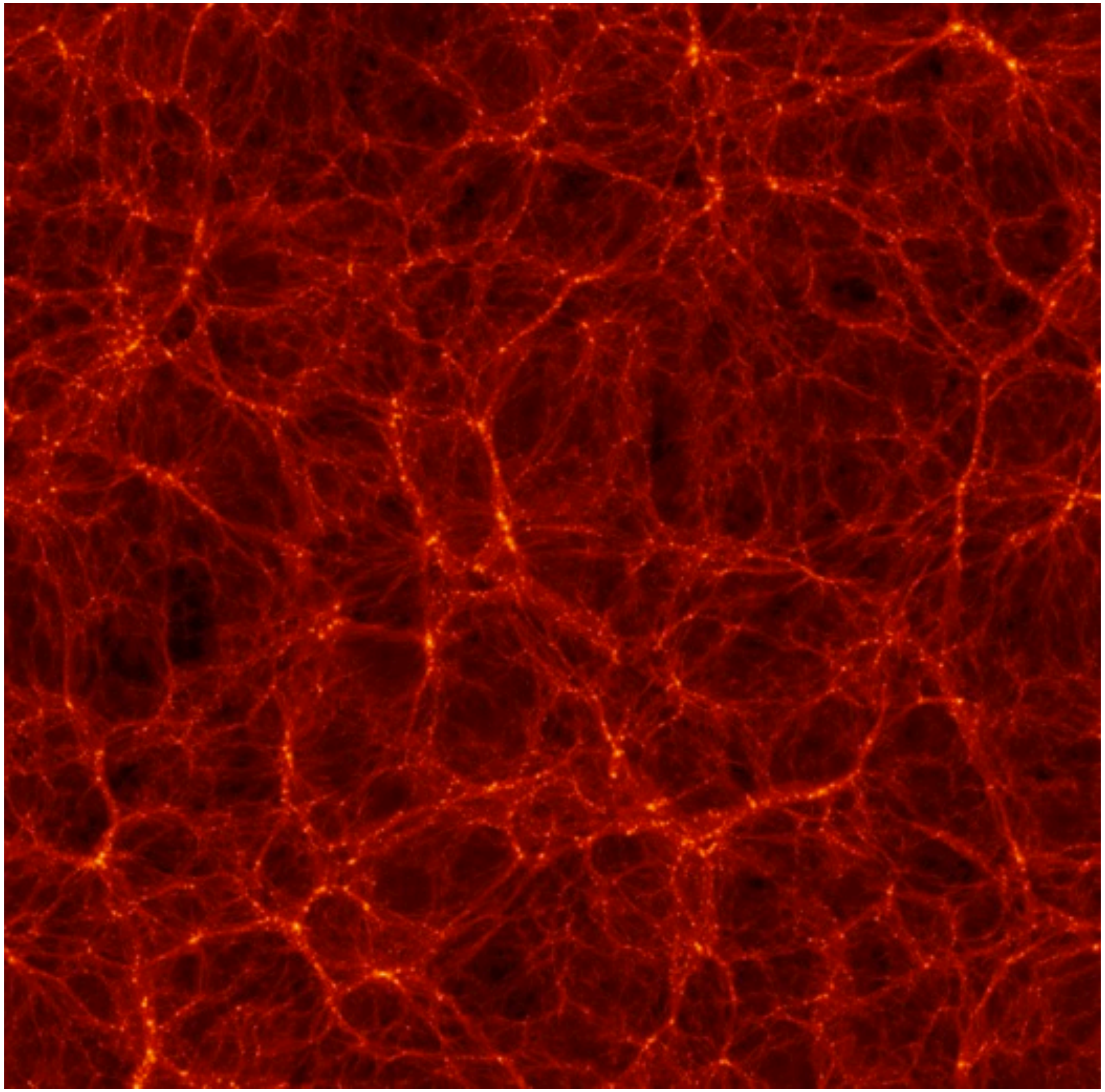


JEF-R, Hoffman, Yepes, Gottloeber, Piontek, Klypin, Steinmetz, MNRAS 2011, 1107.0017

Conclusion #1

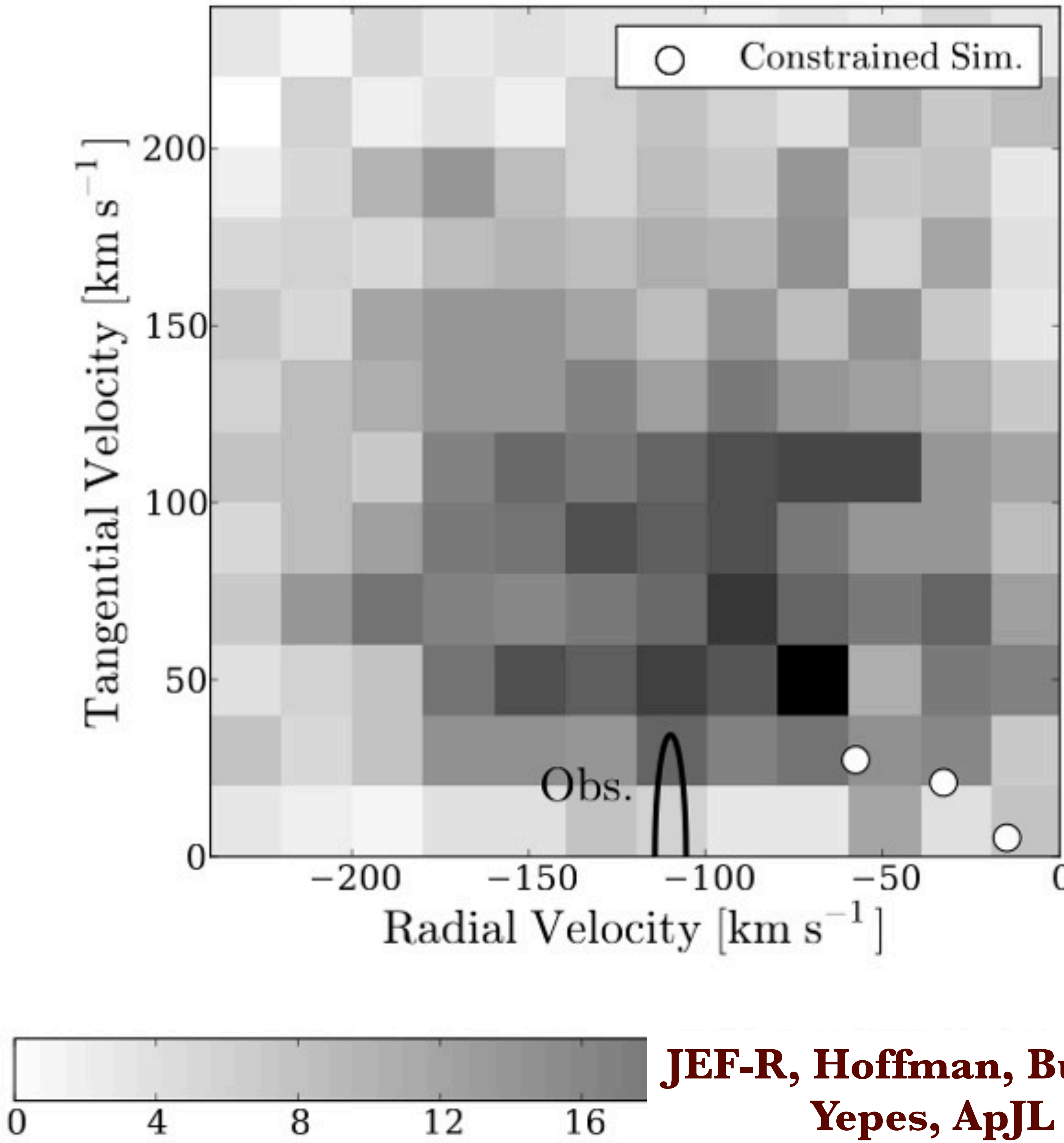
Constraints (large scales + meso scales) produce unusual pairs

Use Bolshoi to study in detail the Isolated Pairs



1st step: kinematics (Sohn, Anderson & van der Marel 2012)

LG kinematics is uncommon in LCDM



JEF-R, Hoffman, Bustamante, Gottloeber, Yepes, ApJL 2013, 1303.2690

Because it is uncommon, it is difficult to build large samples

Physical property	(%) Pairs consistent with observations (1-σ) (full sample)
$v_{\rm r}$-$v_{\rm t}$	(0.4%) 8/1923
$e_{\rm tot}$-$l_{\rm orb}$	(15%)298/1923
$\log_{10}\lambda$	(13%)257/1923
$r_{\rm t} = v_{\rm t}/v_{\rm r}$	(12%)242/1923

JEF-R, Hoffman, Bustamante, Gottloeber, Yepes, ApJL 2013, 1303.2690

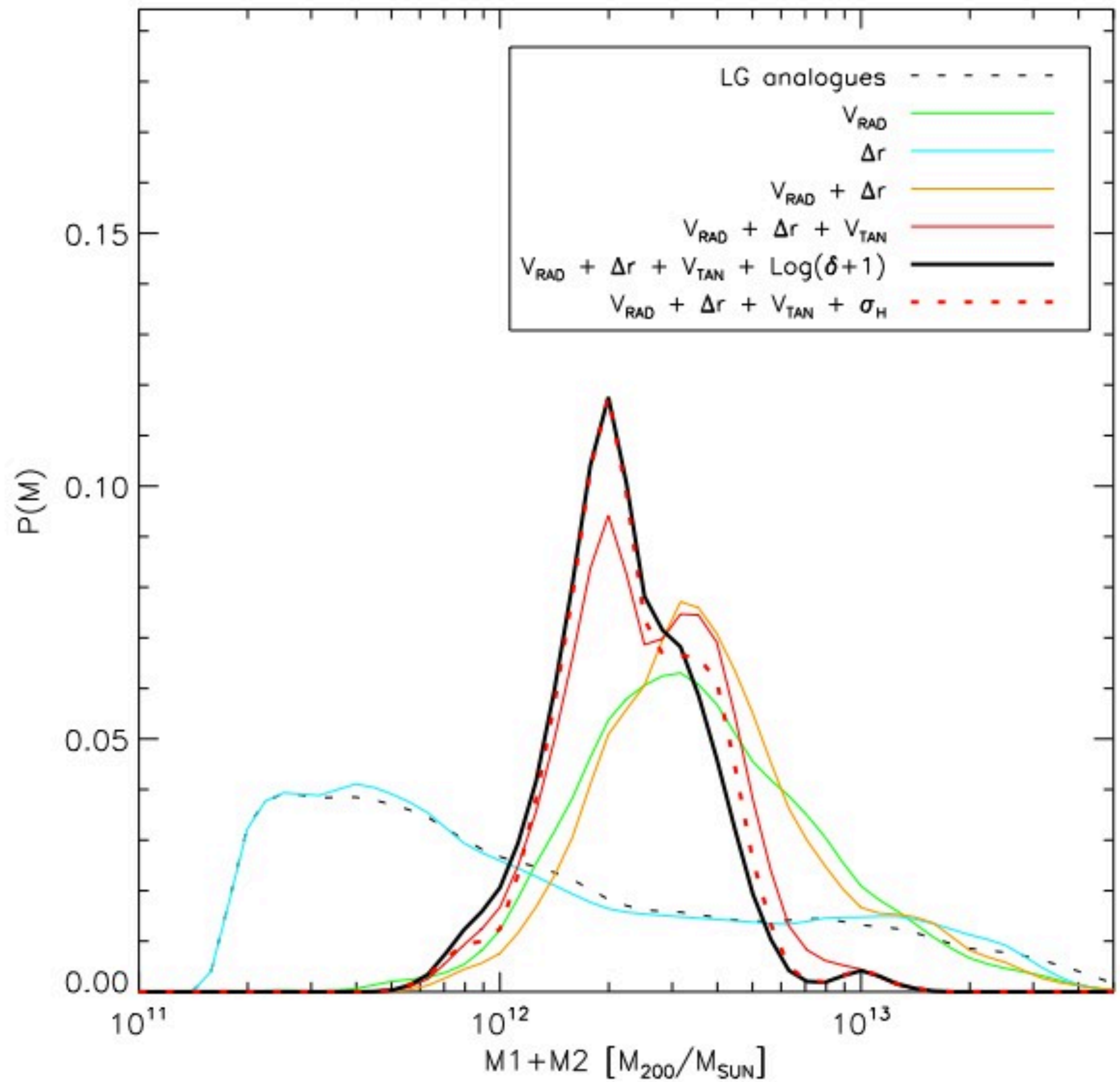
Larger samples can be constructed looking back in time for the special kinematic configurations

TABLE 1
MASS LIKELIHOOD OF MW+M31 PAIRS IN LG ANALOGUES

Constraints	$\log(M_{200c}/M_{\odot})$	68% conf. internval	90% conf. interval	N pairs
$V_{RAD} + \Delta r$	12.60	-0.10 +0.12	-0.31 +0.45	347
$V_{RAD} + \Delta r + V_{TAN}$	12.45	-0.12 +0.11	-0.25 +0.25	88
$V_{RAD} + \Delta r + V_{TAN} + \log(1+\delta)$	12.38	-0.07 +0.09	-0.25 +0.24	66
$V_{RAD} + \Delta r + V_{TAN} + \sigma_H$	12.39	-0.07 +0.13	-0.19 +0.27	64
$V_{RAD} + \Delta r + V_{TAN} + \log(1+\delta) + 1$ Mpc[a]	12.62	-0.11 +0.13	-0.28 +0.26	66
$V_{RAD} + \Delta r + V_{TAN} + \sigma_H + 1$Mpc	12.62	-0.11 -0.13	-0.28 +0.27	64

Gonzalez, Kravtsov, Gnedin, ApJ 2014, 1312.2587

LG kinematics are equivalent to mass selection



Gonzalez, Kravtsov, Gnedin, ApJ 2014, 1312.2587

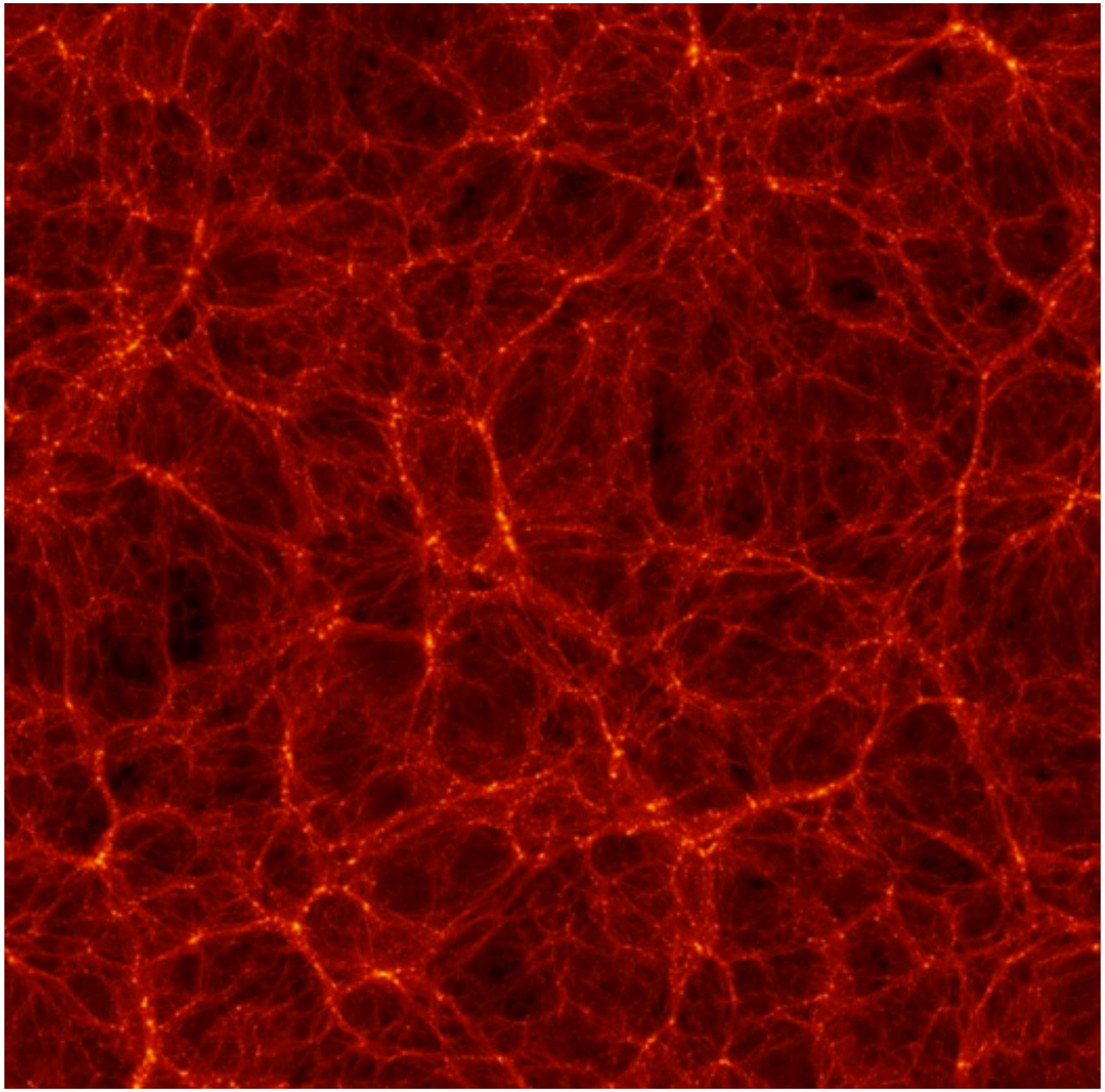
Conclusion #2

The observed LG kinematics is not common in LCDM.

Conclusion #3

Requiring consistency with observations imposes a tight constraint on the LG mass.

Use Bolshoi to study in detail the environment of LG pairs



Data publicly available

CosmoSim

The CosmoSim database provides results from cosmological simulations performed within different projects: the MultiDark project, the BolshoiP project, and the CLUES project.

MULTIDARK
Multimessenger Approach for Dark Matter Detection

The Spanish MultiDark Consolider project supports efforts to identify and detect matter, including dark matter simulations of the universe.

MDR1
MDPL
Bolshoi

BolshoiP
Cosmological Simulations

The BolshoiP project contains a simulation like Bolshoi, with the same box size and resolution, but with Planck cosmology.

BolshoiP

CLUES
Constrained Local UniversE Simulations

The CLUES project deals with constrained simulations of the local universe, partially with gas and star formation.

Clues3_LGDM
Clues3_LGGas

Please visit the linked sites for more information about the projects and about the appreciated form of acknowledgment, if the data is used in a scientific publication or proposal. The MultiDark simulations MDR1 and MDPL as well as the Bolshoi simulation are also available via the MultiDark database.

Register to CosmoSim

AIP

CosmoSim.org is hosted and maintained by the Leibniz-Institute for Astrophysics Potsdam (AIP).

German Astrophysical GAVO Virtual Observatory

It is a contribution to the German Astrophysical Virtual Observatory.

The MultiDark and Bolshoi

Environment is defined from the tidal tensor

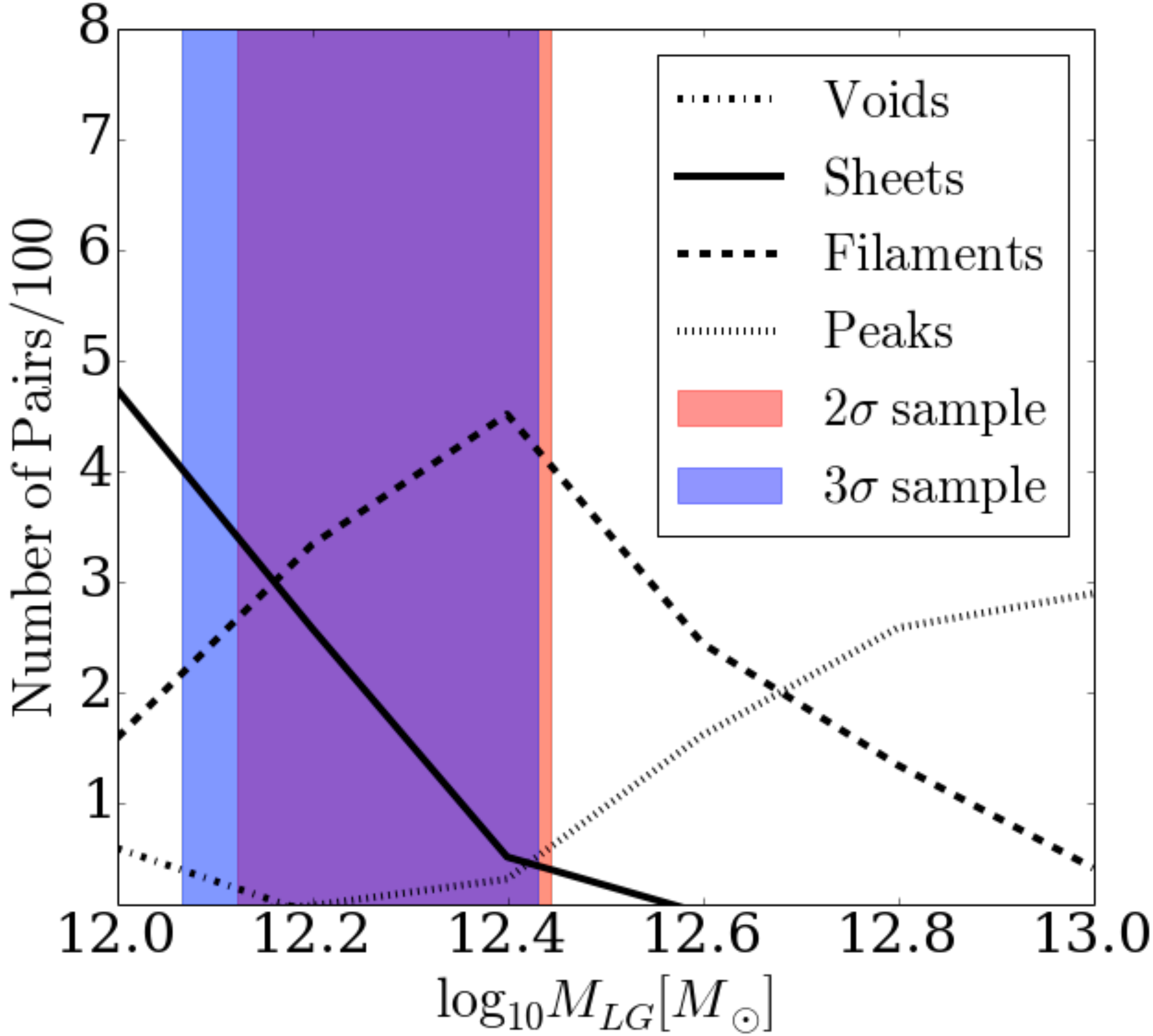
$$T_{ij} = \frac{\partial^2 \phi}{\partial r_i \partial r_j}$$

$$\delta = \lambda_1 + \lambda_2 + \lambda_3$$

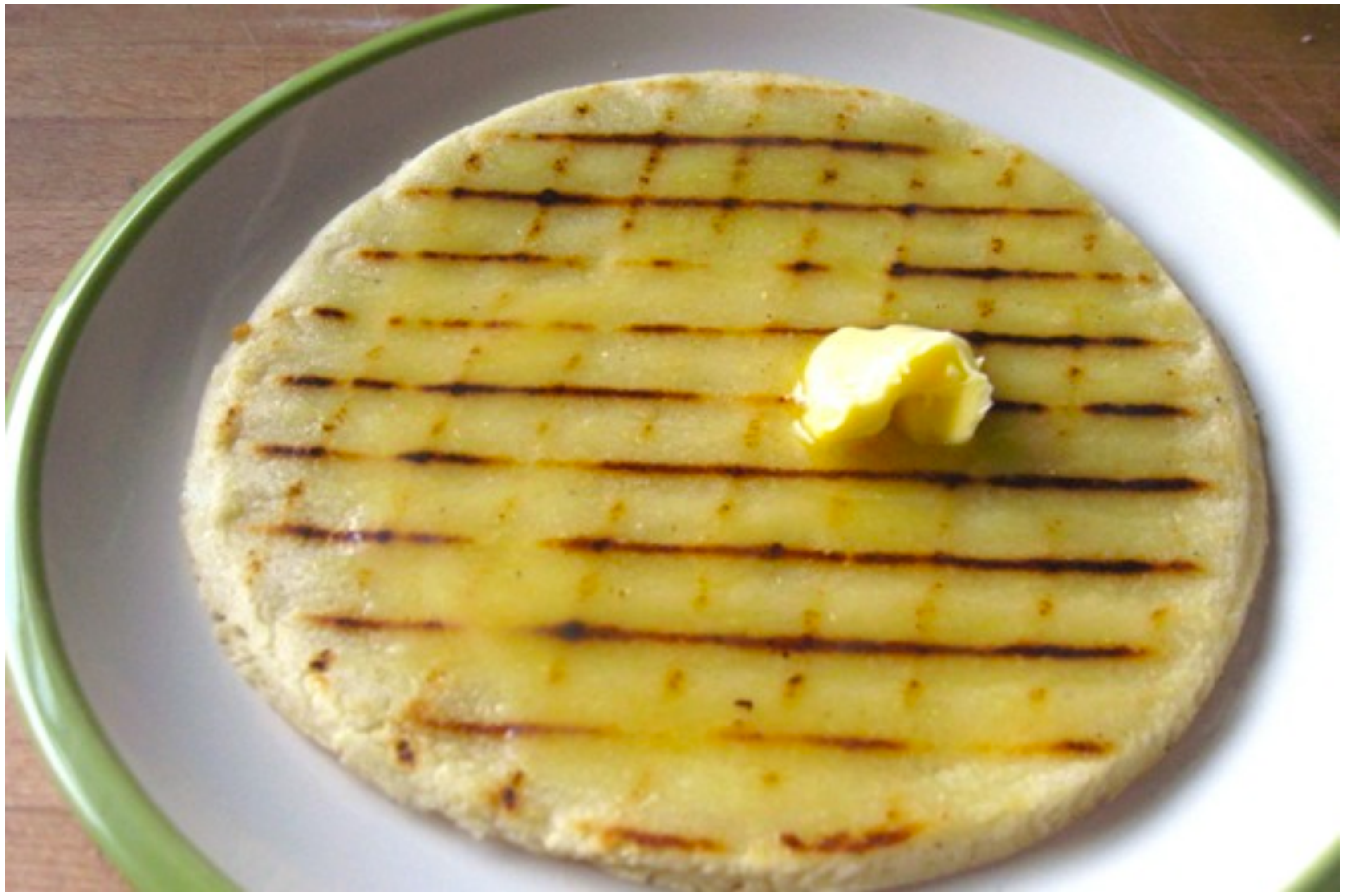
$$e = \frac{\lambda_3 - \lambda_1}{2(\lambda_1 + \lambda_2 + \lambda_3)} \qquad p = \frac{\lambda_1 + \lambda_3 - 2\lambda_2}{2(\lambda_1 + \lambda_2 + \lambda_3)}$$

defined over a grid of 1Mpc/h + 1Mpc/h gaussian smoothing

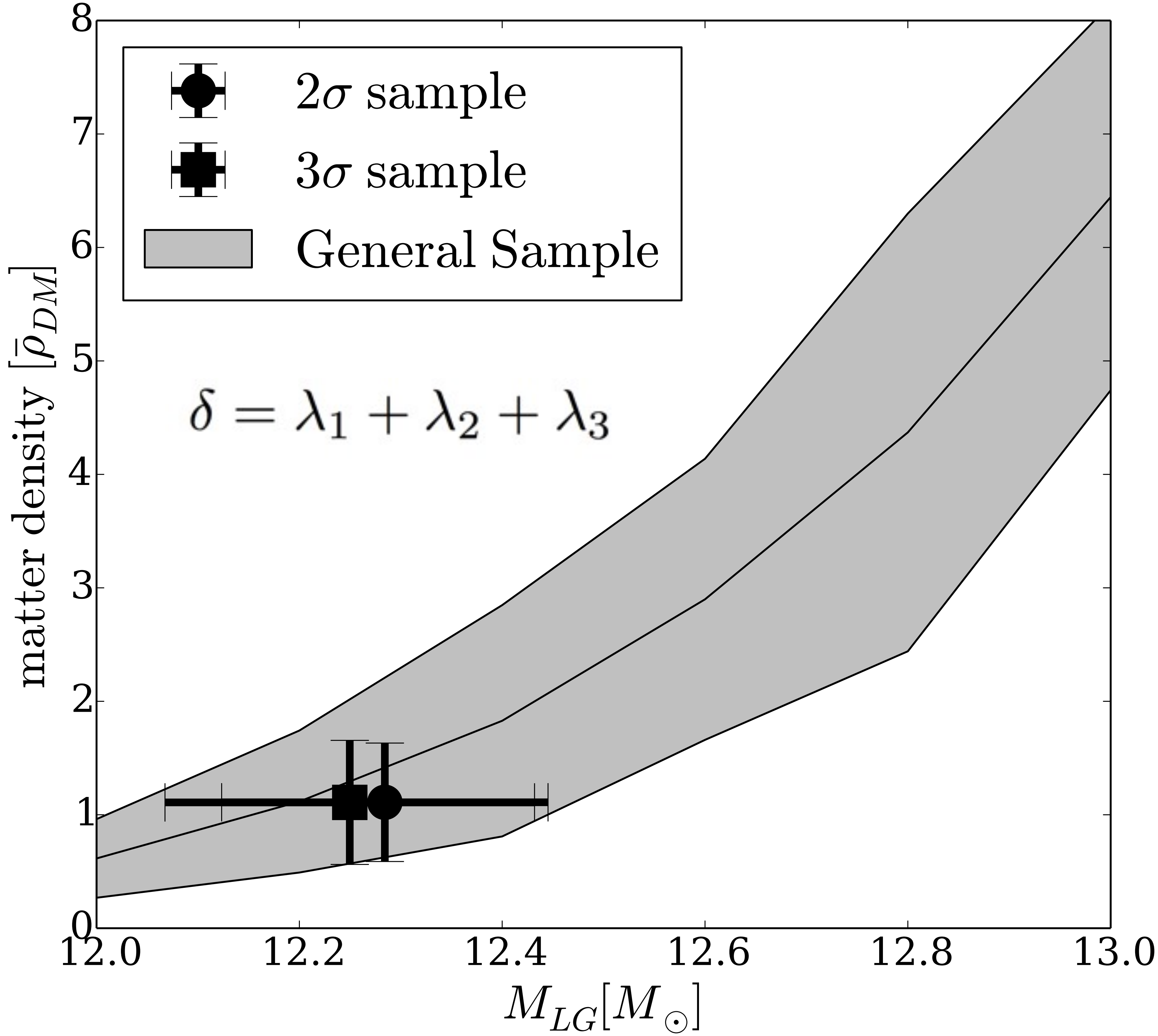
LG mass selects the environment



JEF-R & Gonzalez, ApJ submitted, 1408.3166



LG mass selects the environment



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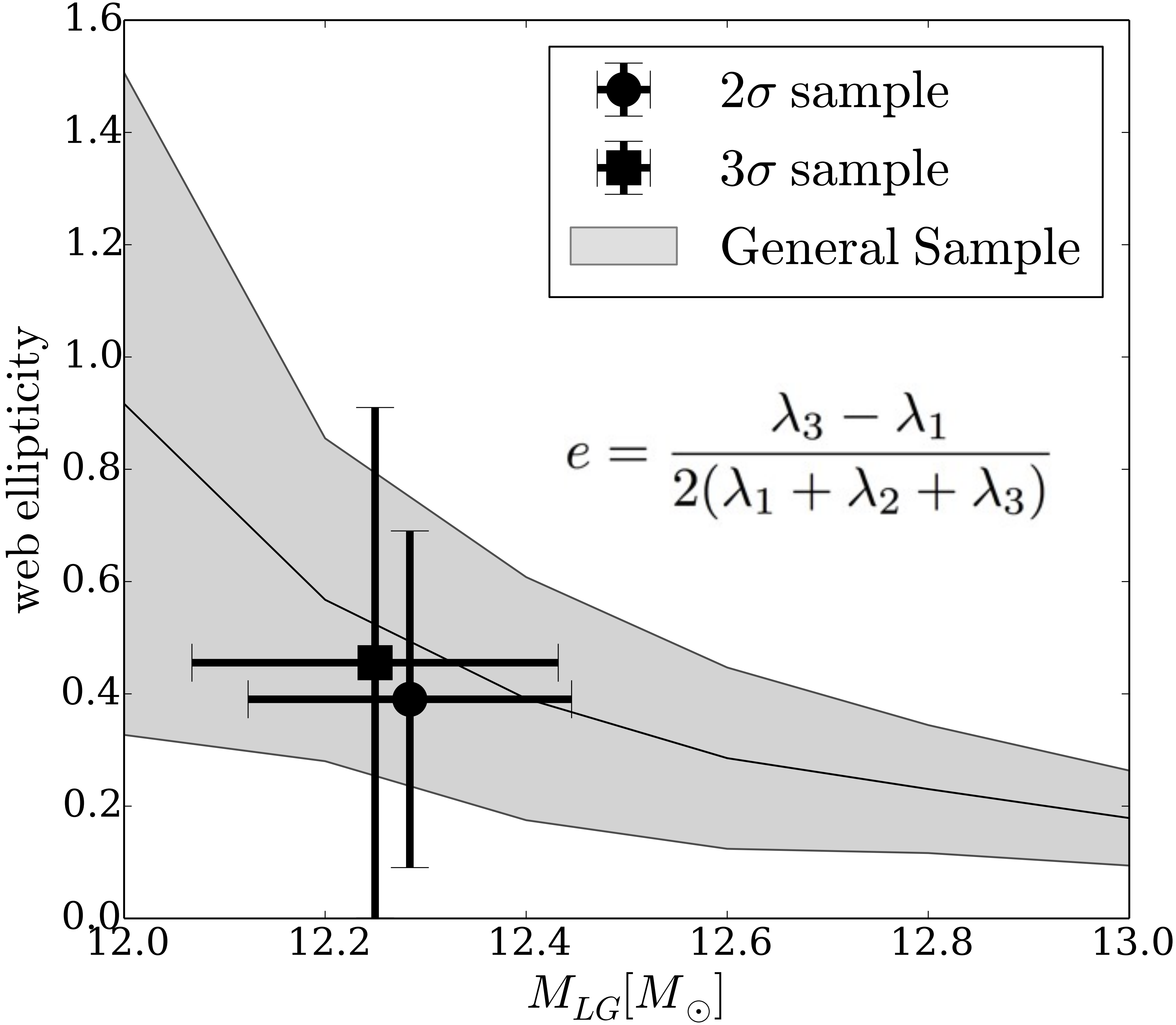

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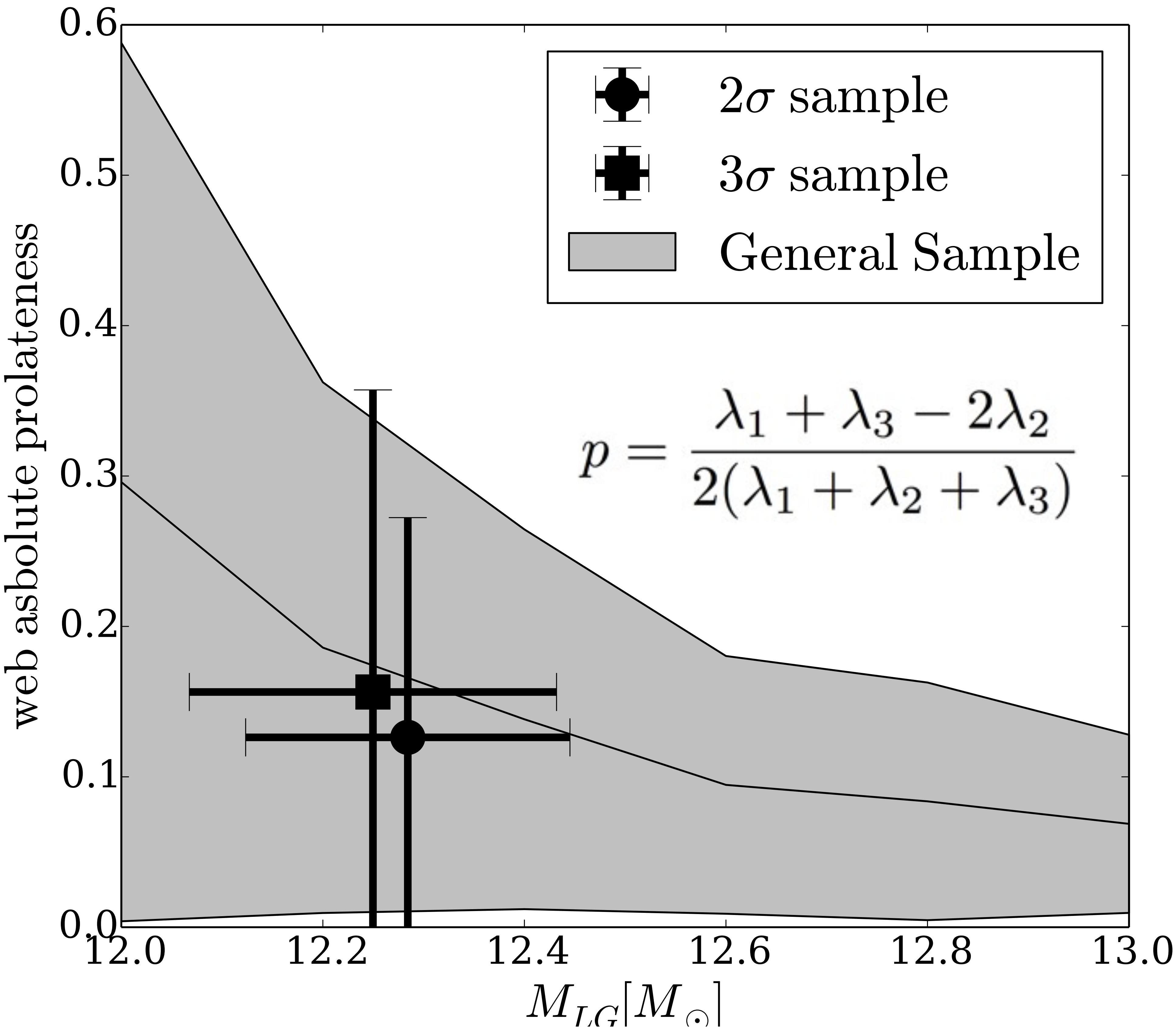

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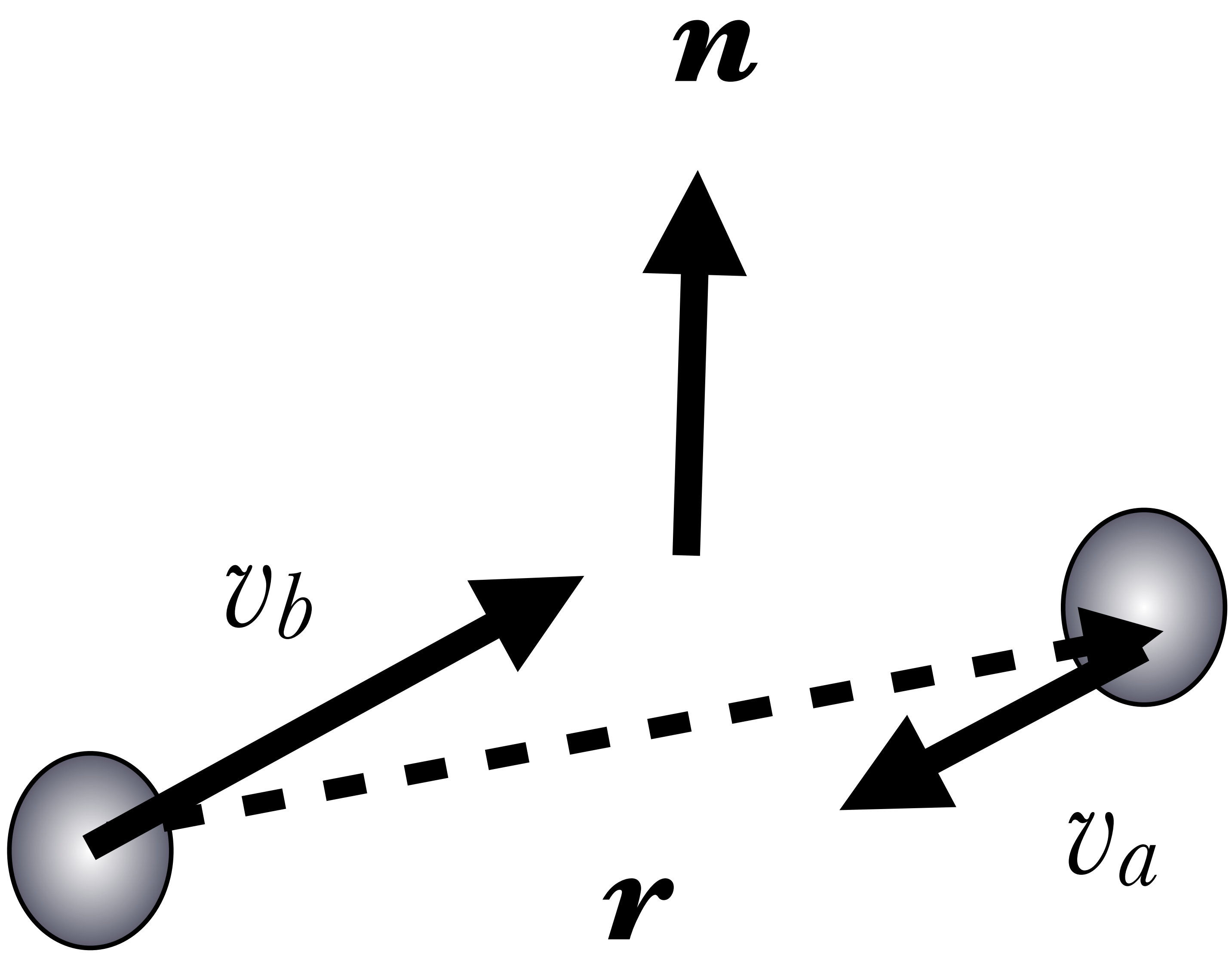
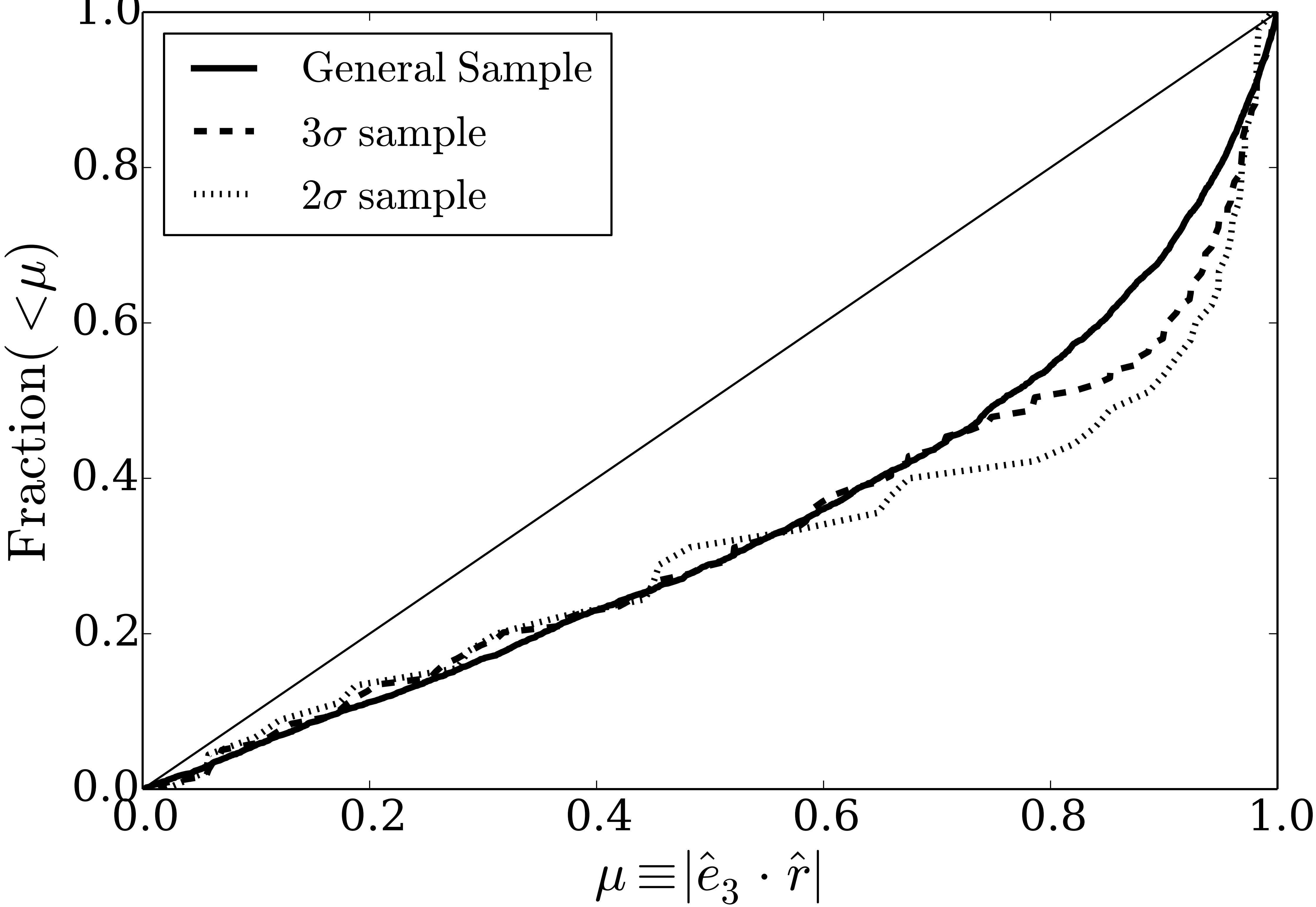
We look for alignments with the cosmic web



CM Frame

strong alignment of **r** with e_3



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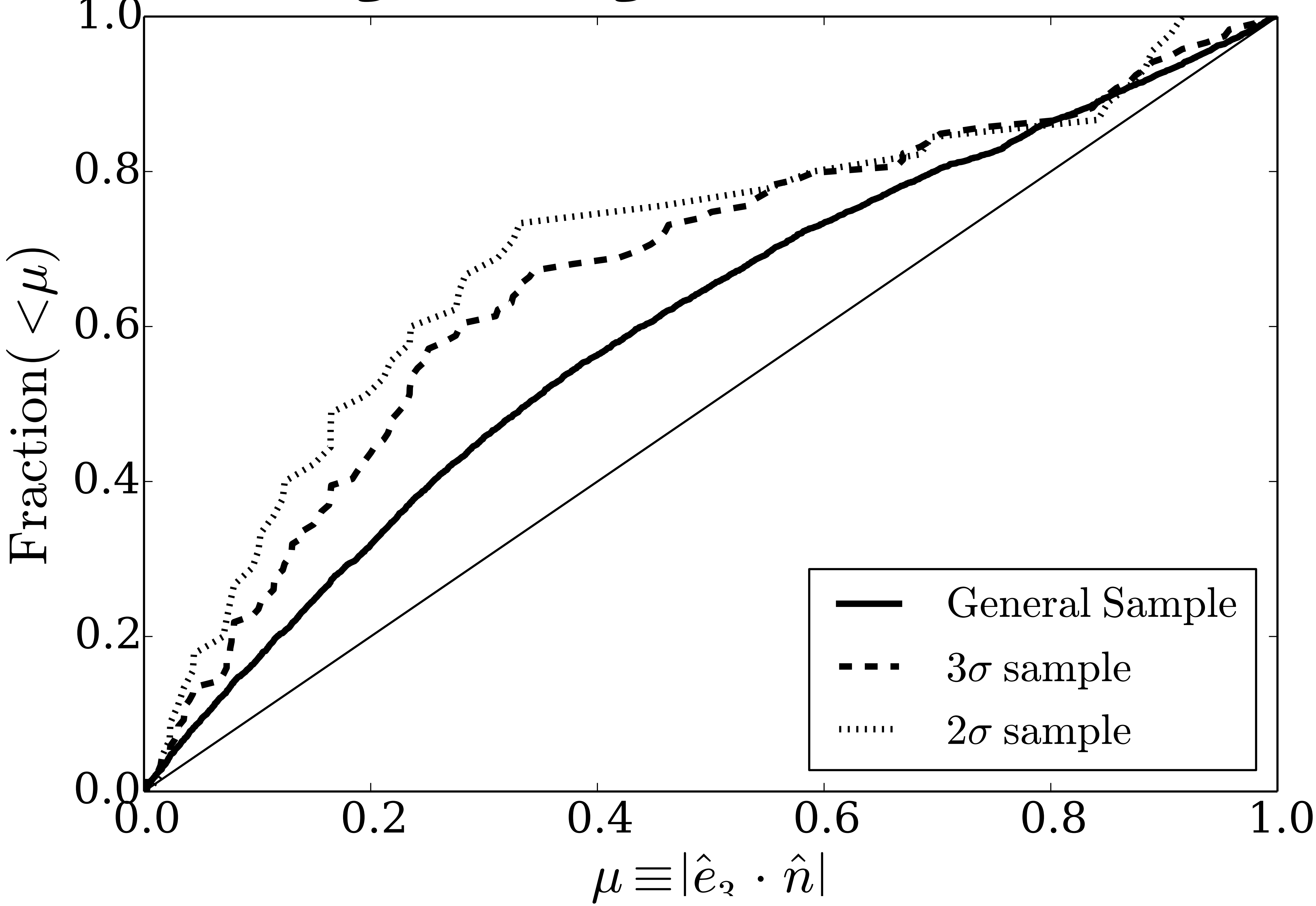
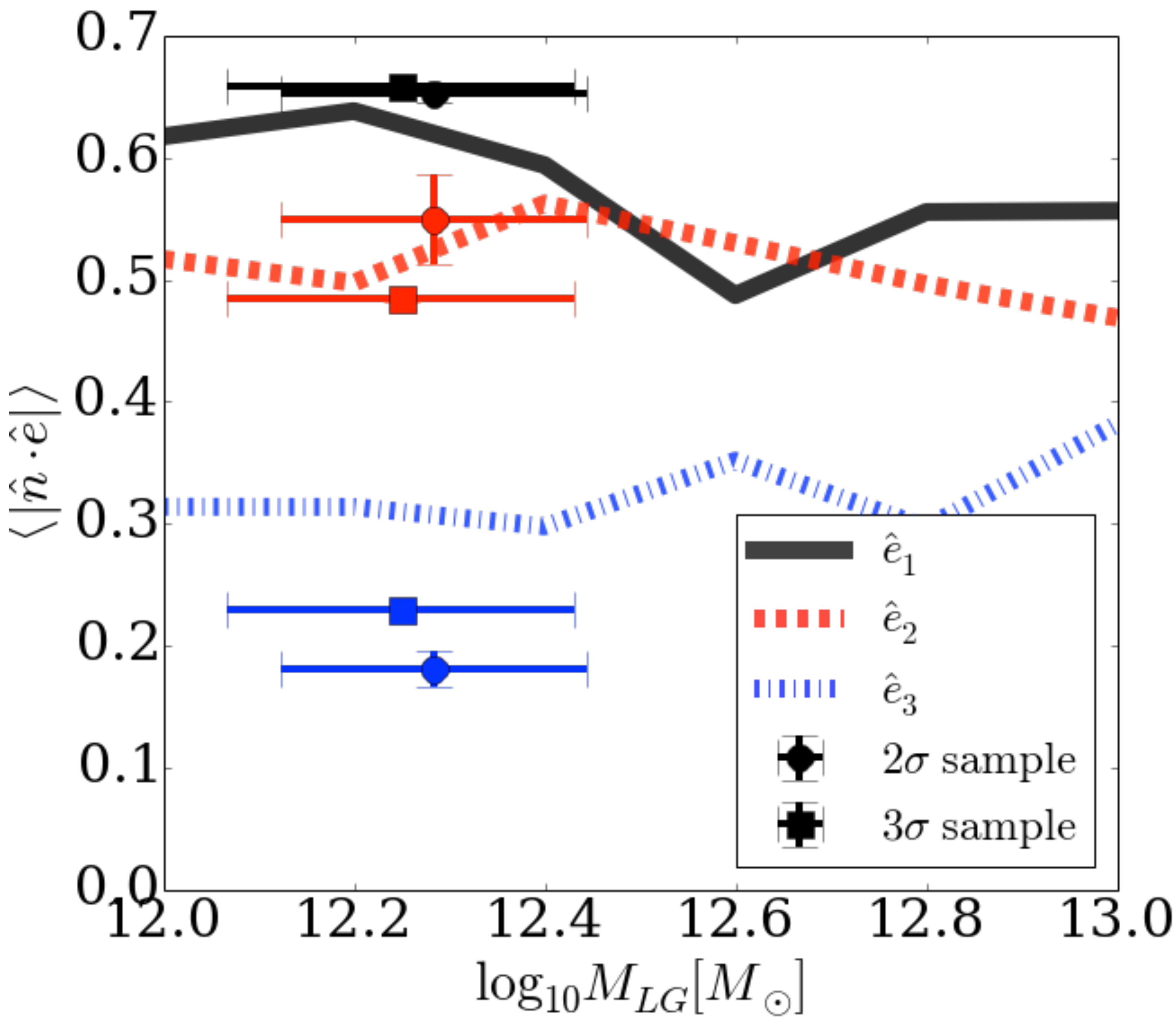
strong anti-alignment of **n** with e_3



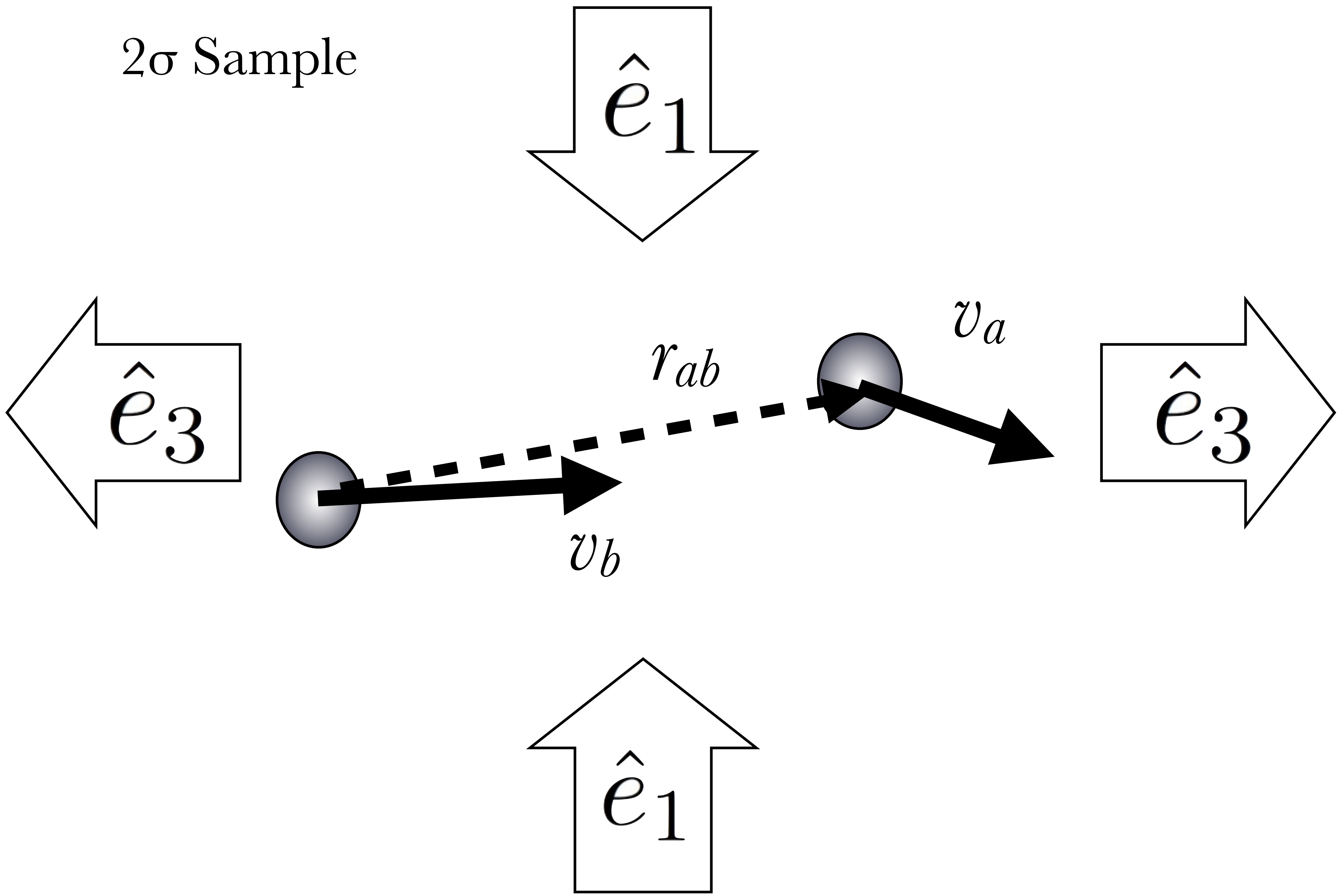
JEF-R & Gonzalez, ApJ submitted, 1408.3166

The strong T-web alignments for pairs is not mass dependent



JEF-R & Gonzalez, ApJ submitted, 1408.3166

Conclusion #4



JEF-R & Gonzalez, ApJ submitted, 1408.3166

Conclusions

- Density field constraints (large scales + meso scales) produce special halo pairs.
- The LG kinematics are not common in LCDM
- LG kinematics impose a tight constraint on the LG mass.
- The LG is most probably located in a filament with the **r** vector along the filament direction.

Sample	Peak	Filament	Sheet	Void
	n (%)	n (%)	n (%)	n (%)
2σ	4 (8.7)	24 (52.2)	17 (36.7)	1 (2.2)
3σ	10 (8.3)	58 (48.3)	47 (39.2)	5 (4.2)
General	1312 (23.9)	1472 (26.9)	1769 (32.3)	927 (16.9)