Leibniz-Institut für Astrophysik Potsdam

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CLUES with Virgo

Jenny Sorce

Annual CLUES meeting

Copenhagen, 11th, *2015*

AIP / Leibniz Institut für Astrophysik

Summary of the Talk given Last August at the Meeting in Potsdam

Introduction:

→ Cosmicflows-2 suffers from biases leading to a general infall onto the local volume.

→ several methods are developed to suppress the infall.

Conclusion:

→ the infall is suppressed.

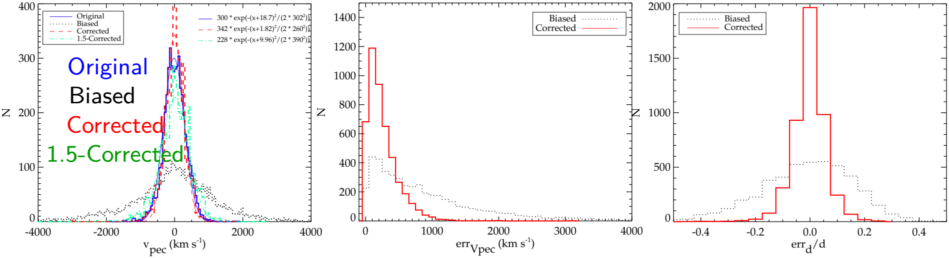
→ The LSS is robust.

But

→ Virgo is not massive enough about 1 order of magnitude too small (10^{13} instead of 10^{14} h^{-1} $M_\odot$)

Changing the method to minimize the biases

Sorce, 2015 (MNRAS)



Iterations on:

$$\text{if } v_{pec} > 0,\ v_{pec\ c} = (1-w)[p(v_{pec} - \sigma_{v_{pec}}) + (1-p)(v_{pec} + \sigma_{v_{pec}})] + w\,v_{pec}$$

$$\text{if } v_{pec} < 0,\ v_{pec\ c} = (1-w)[p(v_{pec} + \sigma_{v_{pec}}) + (1-p)(v_{pec} - \sigma_{v_{pec}})] + w\,v_{pec}$$

then multiplication by 1.5

- p : probability $v_{pec} \notin$ theoretical Gaussian (from the mock) (Sheth and Diaferio, 2001)
- w: weighted uncertainty on v_{pec}

After correction:

- distances computed accordingly: $d_c = (v_{obs} - v_{pec\ c})/H_0$
- 5% fractional error on distances assumed.

Tests on a large selection of mocks and simulations

Infall reduced Gaussian distribution

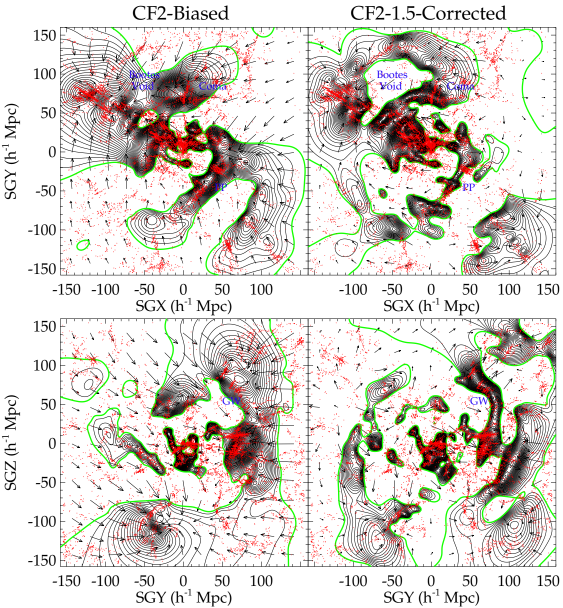
Catalog	Ref. Simu km s^{-1}	Original km s^{-1}	Biased km s^{-1}	Corrected km s^{-1}	Original %	Biased %	Corrected %
errorMock	-90	-80	-761 ± 80	-159 ± 48	99	1	85 ± 8
haloMock	-90	-71 ± 19	-816 ± 50	-142 ± 32	97 ± 2	1	88 ± 8
simuMock	-26 ± 159	-46 ± 107	-804 ± 79	-60 ± 83	97 ± 2	1 ± 1	88 ± 12
All	-77 ± 70	-70 ± 47	-792 ± 71	-133 ± 62	98 ± 2	2 ± 2	87 ± 9
CF2	/	/	-819	-36	/	3	94

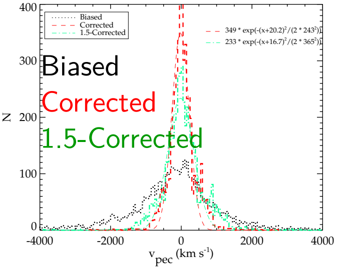
1-σ scatter of cell-to-cell comparisons

	Ref.Simu/ Original Full km s^{-1}	Original/Biased Full / Div km s^{-1}/ km s^{-1}	d unit of density	Original/Corrected Full / Div km s^{-1}/ km s^{-1}	d unit of density
errorMock	84	89 ± 5 / 69 ± 3	0.14	**71 ± 3 / 69 ± 2**	0.14
haloMock	86 ± 2	97 ± 5 / 73 ± 3	0.14	**72 ± 3 / 71 ± 4**	0.14
simuMock	85 ± 1	95 ± 5 / 77 ± 4	0.14	**81 ± 7 / 71 ± 5**	0.14
All	85 ± 2	93 ± 6 / 72 ± 4	0.14	**73 ± 6 / 70 ± 3**	0.14

Results gathered from 5 simulations and 66 mocks: 25 biased mocks, 25 corrected mocks and 16 original mocks.

Application on Cosmicflows-2



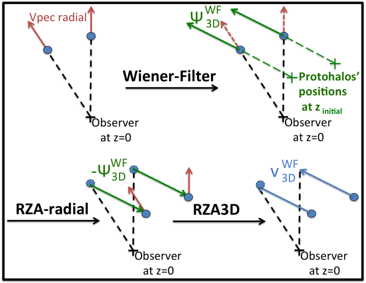


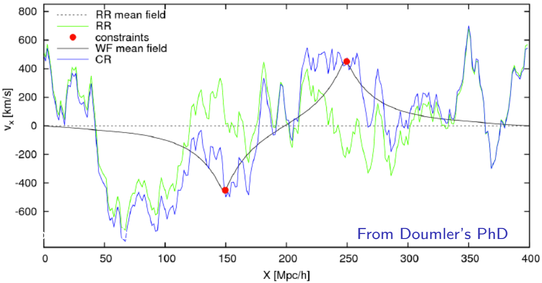
- General infall suppressed
- Structures more sharply defined

↪ Let's see if we have Virgo now.

First, let's check that the robustness of LSS and flows is preserved.

Reverse Zel'dovich Approximation: A reminder

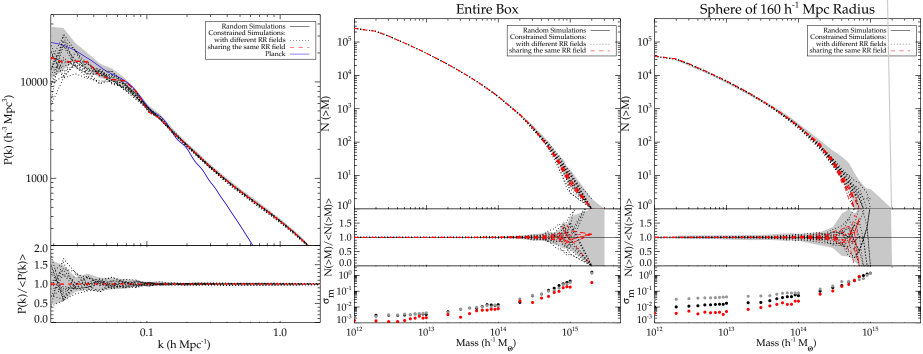




Cosmicflows-2 → WF → RZA → CR (∼ WF+RR) → white noise → increase resolution (random small scale features) → convert back white noise to build initial conditions → run constrained simulations

Linear Theory at 1st order valid down to 2 h^{-1} Mpc

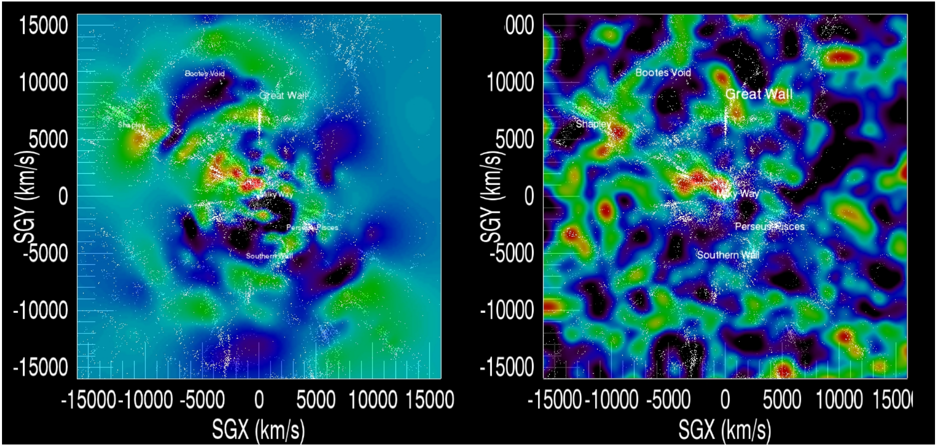
Power Spectra & Mass functions



The Large Scale Structure

At $z = 0$,

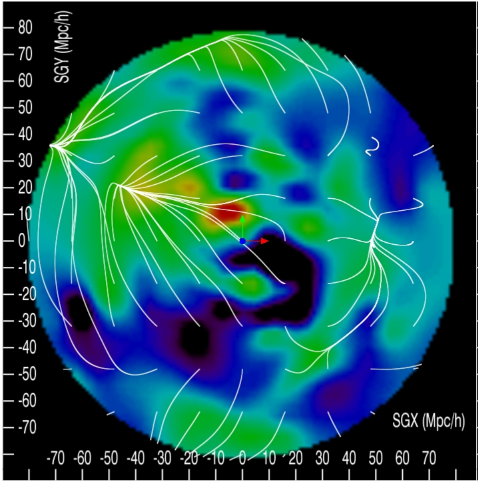
Reconstruction | Simulation



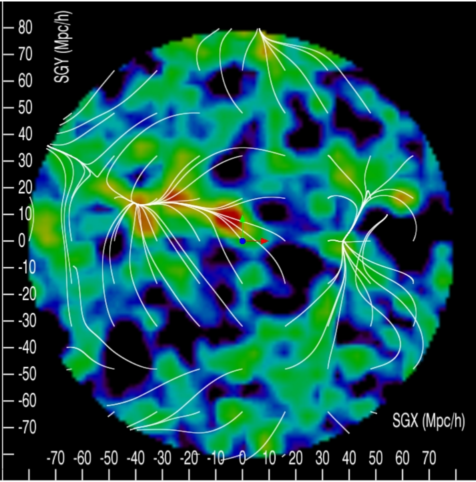
Periodic Boundary Conditions, L=500 h^{-1} Mpc , $n=512^3$

The Laniakea Supercluster

Wiener-Filter Reconstruction

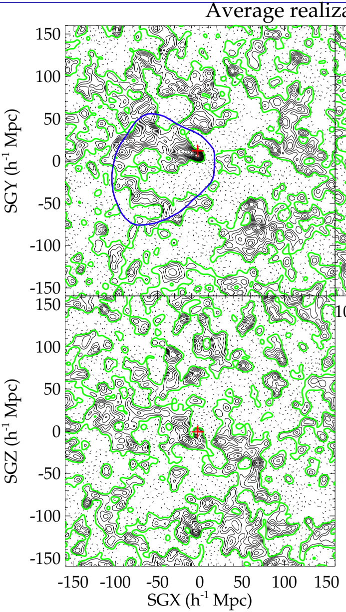


One Constrained Simulation



In 3D next to each other!

Robust Large-Scale Environment

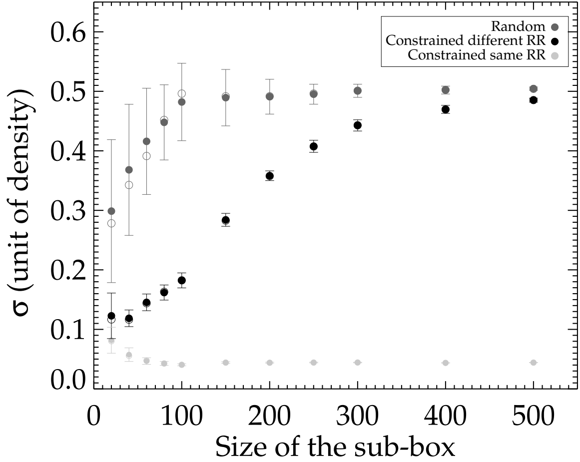


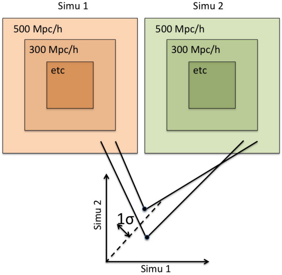
Fifteen Simulations

Major Attractors and Voids of the Local Universe are **simulated repetitively**

→ **robust Large-Scale Environment to study local objects**

Robust Large-Scale Environment





Smoothing: 5 h^{-1} Mpc

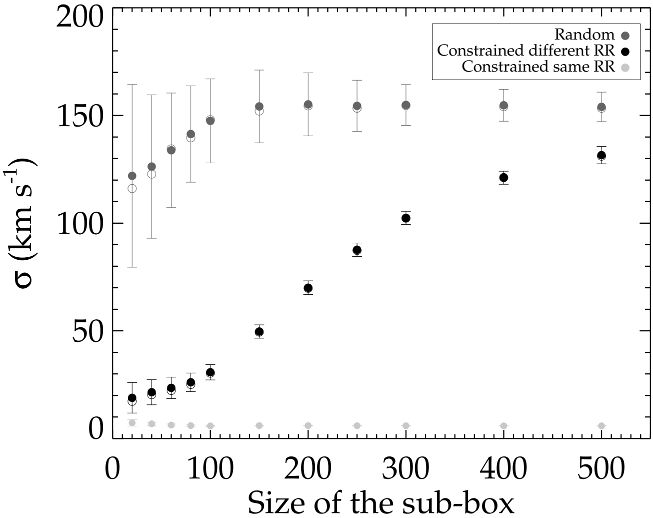
Cell size: 1 - 2 h^{-1} Mpc

TO DO: Comparison between different codes used to increase the resolution (Klypin & Holtzman)

Mean, median and scatter of 1-σ scatters in cell-to-cell comparisons

Robust Large-Scale Environment → to study local structures and objects

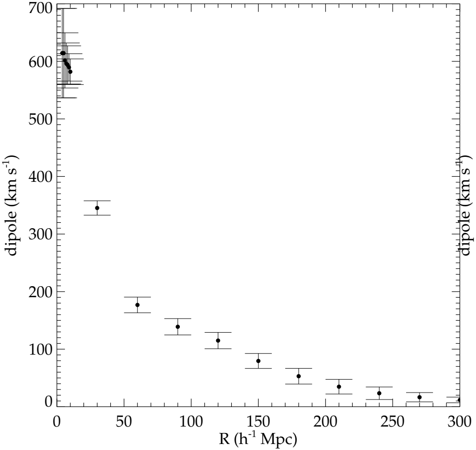
Robust Large-Scale Cosmic Flows



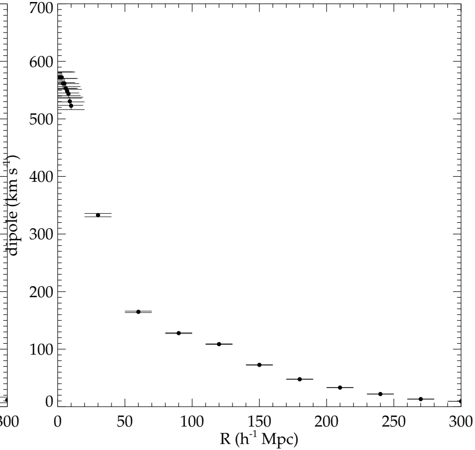
Mean, median and scatter of 1-σ scatters in cell-to-cell comparisons

Robust Large-Scale Cosmic Flows → to study local structures and objects

Bulk Flow - Large Scale

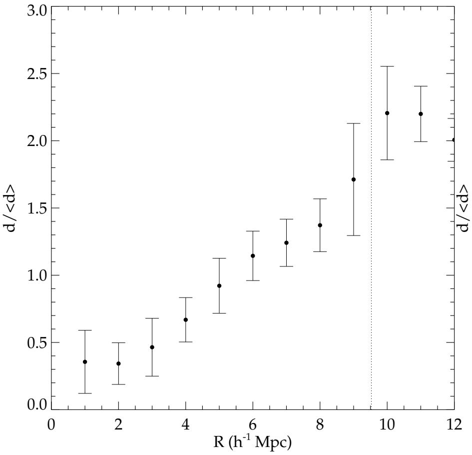


Constrained different RR field

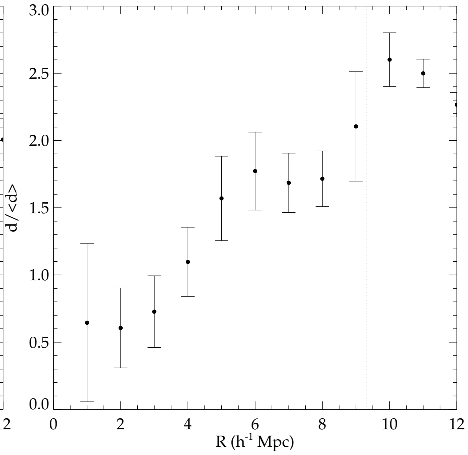


Constrained same RR field

Density - Small Scale

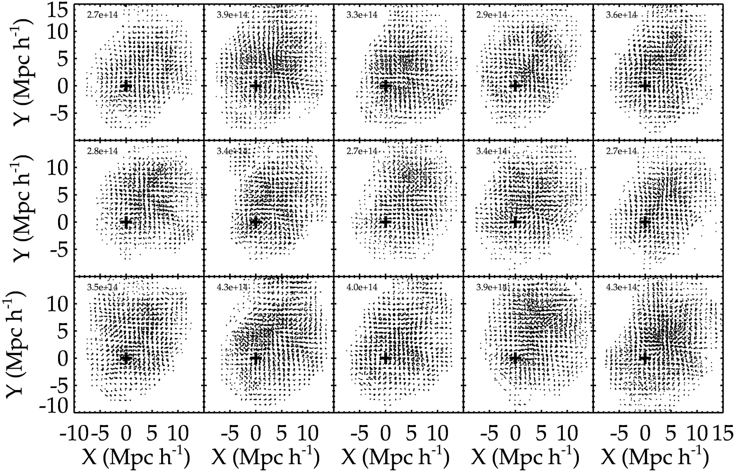


Constrained different RR field



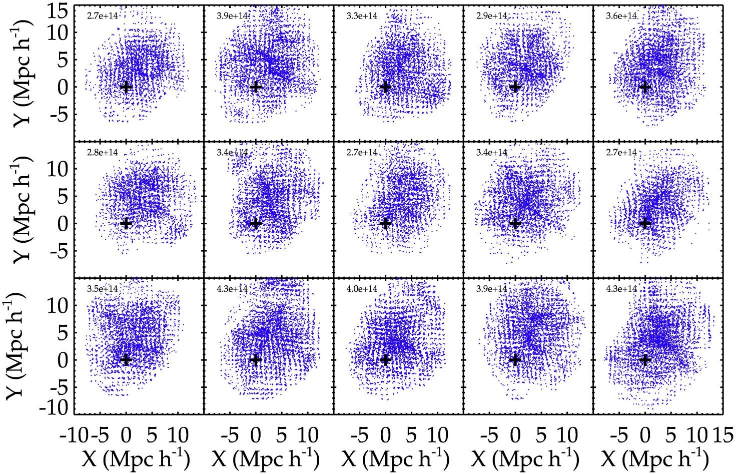
Constrained same RR field

Observed Virgo & Simulated dark matter halos



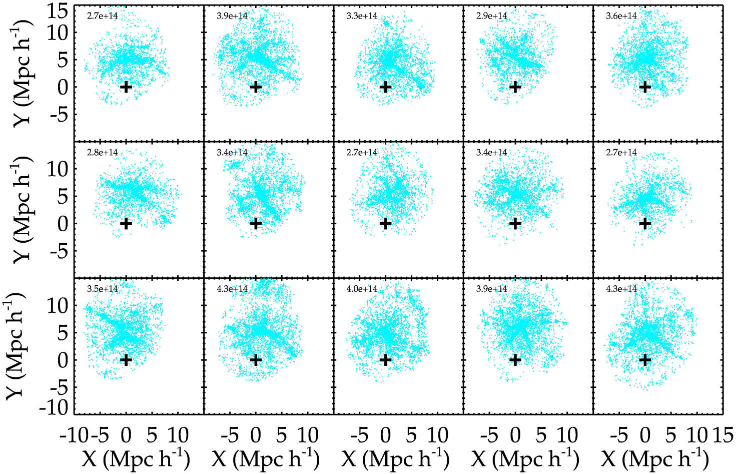
Dark Matter Haloes - Virgo Candidates: Particles at z= 10.

Observed Virgo & Simulated dark matter halos



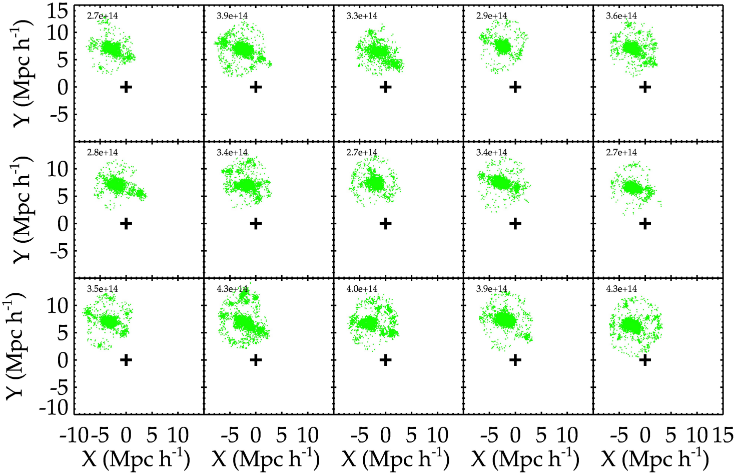
Dark Matter Haloes - Virgo Candidates: Particles at z= 5.

Observed Virgo & Simulated dark matter halos



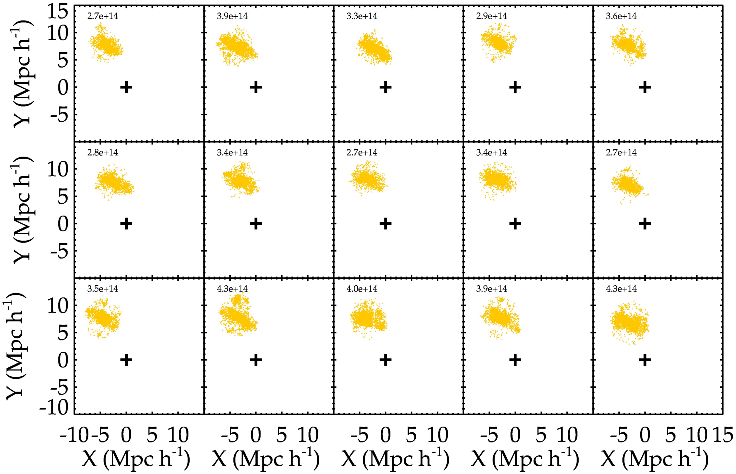
Dark Matter Haloes - Virgo Candidates: Particles at z= 2.

Observed Virgo & Simulated dark matter halos



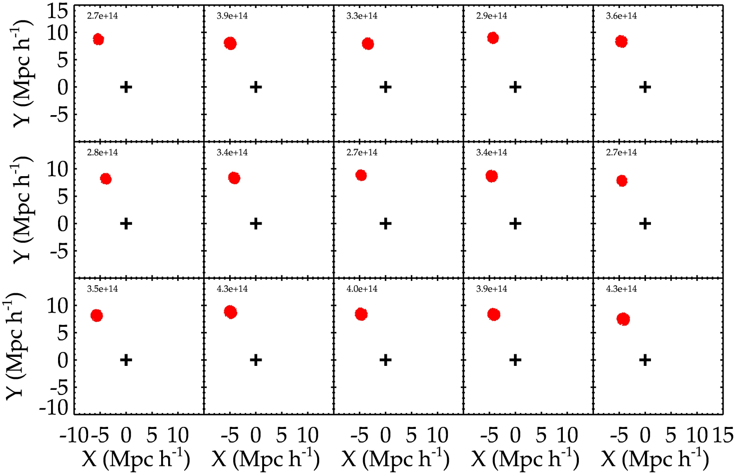
Dark Matter Haloes - Virgo Candidates: Particles at z= 0.5

Observed Virgo & Simulated dark matter halos



Dark Matter Haloes - Virgo Candidates: Particles at z= 0.25

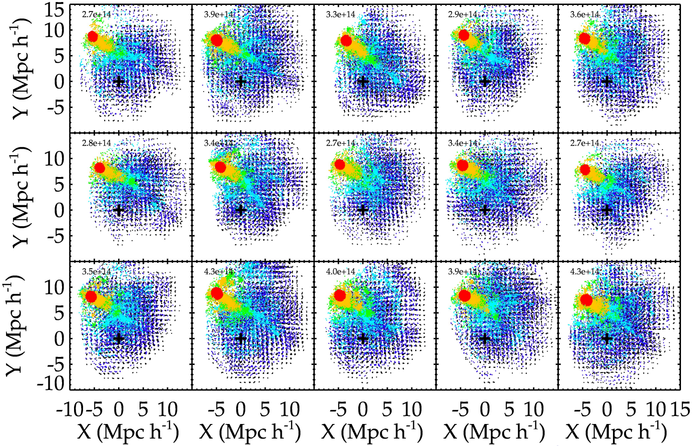
Observed Virgo & Simulated dark matter halos



Dark Matter Haloes - Virgo Candidates: Particles at z= 0.

Observed Virgo & Simulated dark matter halos

Virgo - Diff. 'CR' Seeds



Dark Matter Haloes - Virgo Candidates:

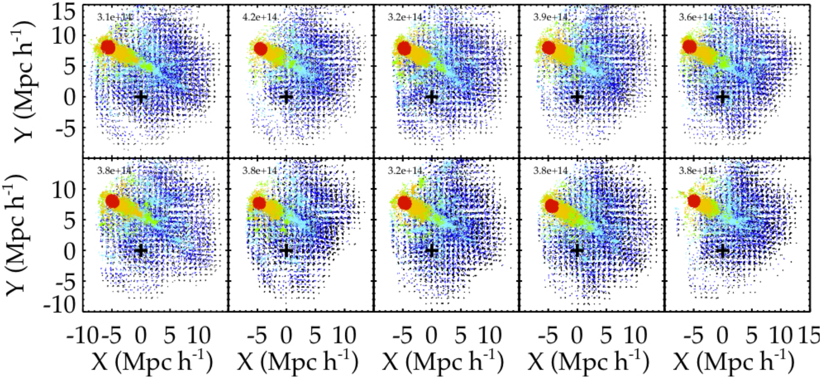
- Similar formation / evolution
- Shift $\sim$ 3-4 h^{-1} Mpc
- Mass within $\sim$ [0.5,2] estimated mass (Ludlow & Porciani 2011)

One color per redshift:
10, 5, 2, 0.5, 0.25, 0

M_{200}

Observed Virgo & Simulated dark matter halos

Virgo - Diff. 'Increasing Res.' Seeds



Dark Matter Haloes - Virgo Candidates:

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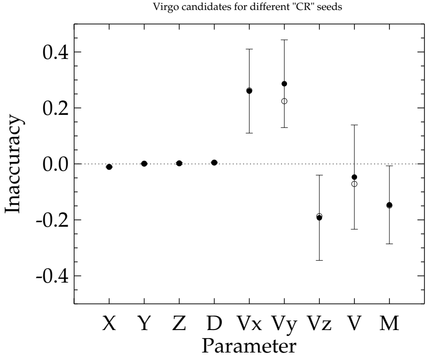
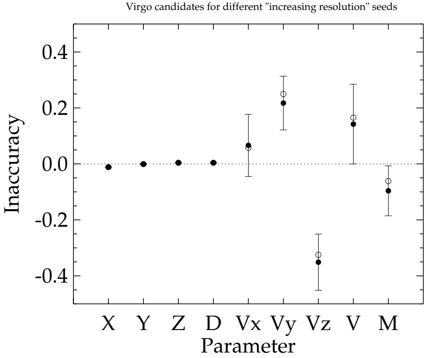
One color per redshift:
10, 5, 2, 0.5, 0.25, 0

M_{200}

Properties of Virgo Candidates

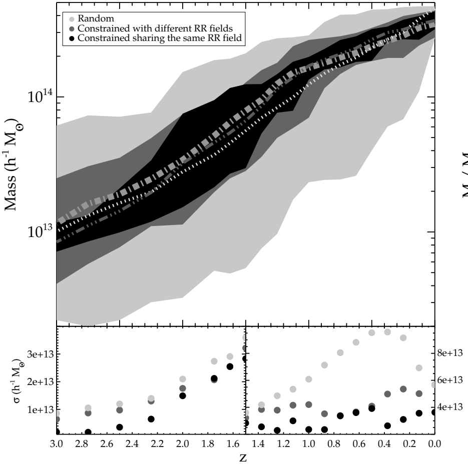
$$Inaccuracy = \frac{(Comp_{Simu} - Comp_{Obs})}{typical\ value}$$

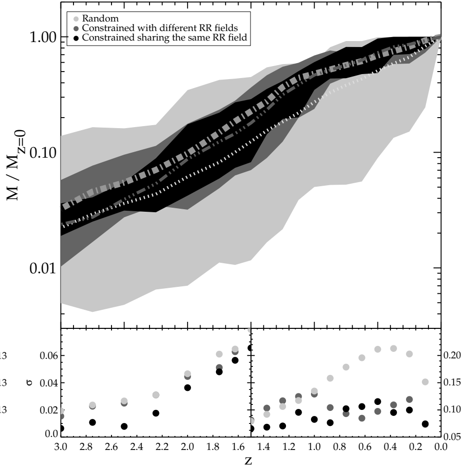




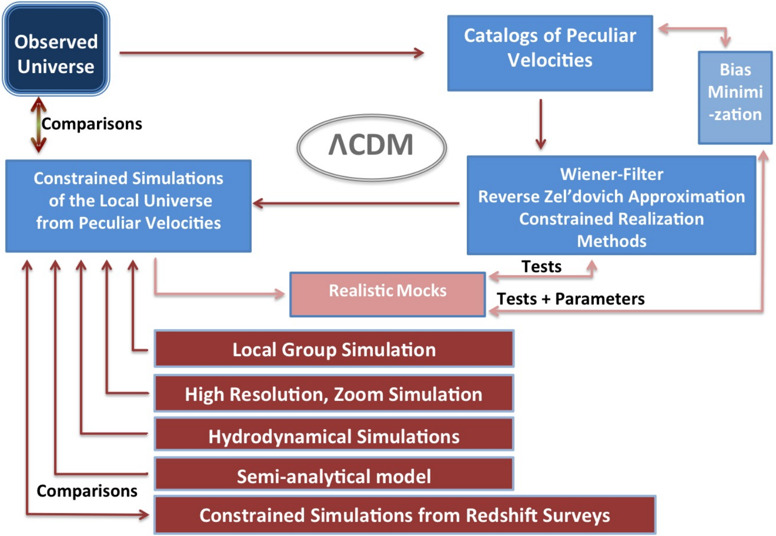
- Small scatter between the different simulations
- Good agreement with observational data

Merging Histories of Virgo Candidates





Conclusion & Prospectives



Acknowledgements

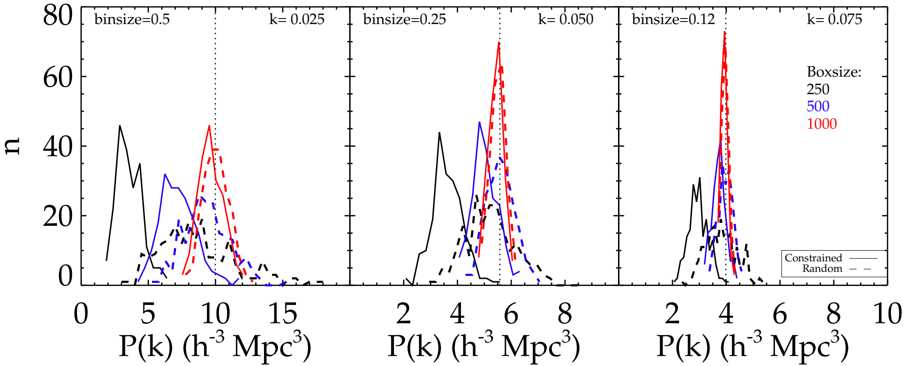
Thank you, Merci, Danke,

Gracias, Grazie, Spasibo,

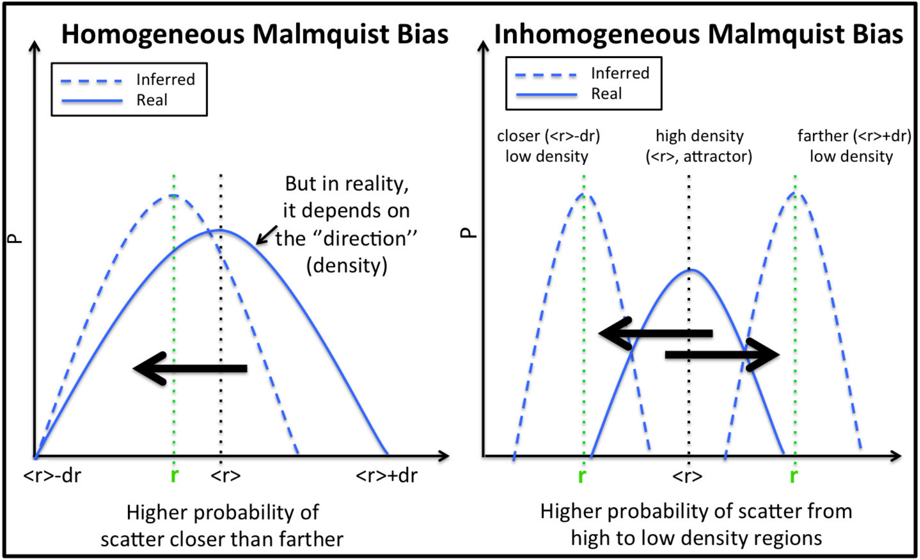
Mahalo, Xièxie, Arigatô,

Toda, Tak ...

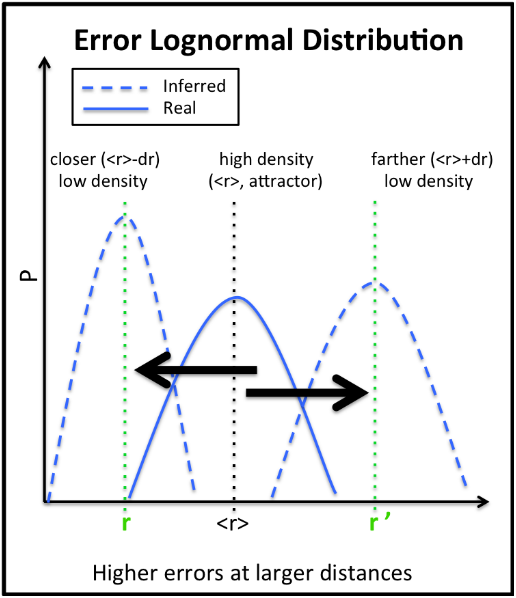
Power Spectra



Deeper Catalogs CF2-3: Stronger Biases' Effects



Deeper Catalogs CF2-3: Stronger Biases' Effects



Error Lognormal Distribution:

Example:

μ=35±0.8 mag (20% on d) ⇒

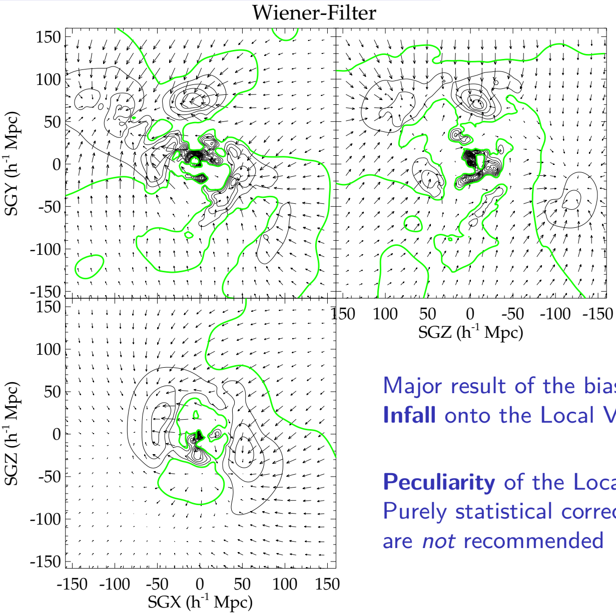
d=100 [69;145] Mpc $\boxed{(-31;+45)}$

H_0=75 km s^{-1} Mpc^{-1} & v_{obs}=7500 km s^{-1}⇒

v_{pec}=0 $\boxed{[2311;-3338]}$ km s^{-1}

Asymmetry

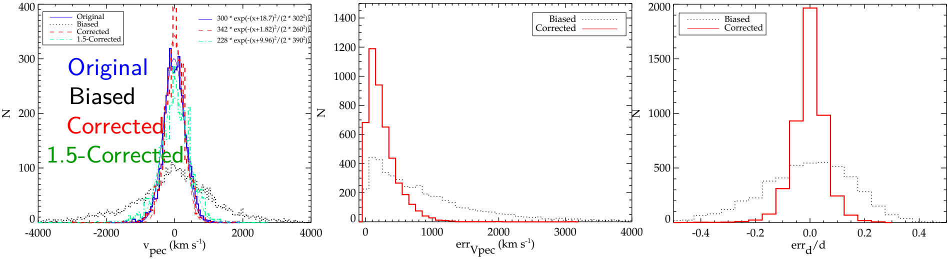
General **Infall** onto the Local Volume



Major result of the biases: General **Infall** onto the Local Volume

Peculiarity of the Local Universe: Purely statistical correction methods are *not* recommended

Proposition of a Method to Minimize the (Asymmetry) Bias(es)



Iterations on:

$$\textit{if} \ \ v_{pec} > 0, \ \ v_{pec\ c} = (1-w)[p(v_{pec}-\sigma_{v_{pec}}) + (1-p)(v_{pec}+\sigma_{v_{pec}})] + w\, v_{pec}$$

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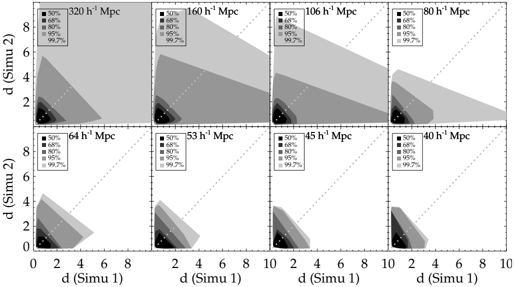
then multiplication by 1.5

- p : probability $v_{pec} \notin$ theoretical Gaussian (from the mock) (Sheth and Diaferio, 2001)
- w: weighted uncertainty on v_{pec}

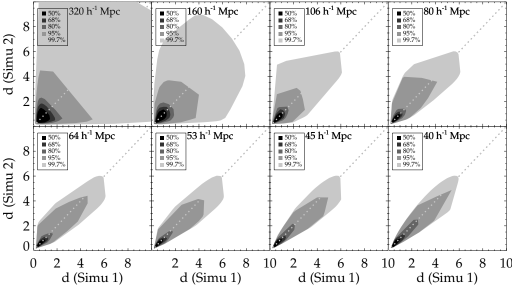
After correction:

- distances computed accordingly: $d_c = (v_{obs} - v_{pec\ c})/H_0$
- 5% fractional error on distances assumed.

Robust Large-Scale Environment



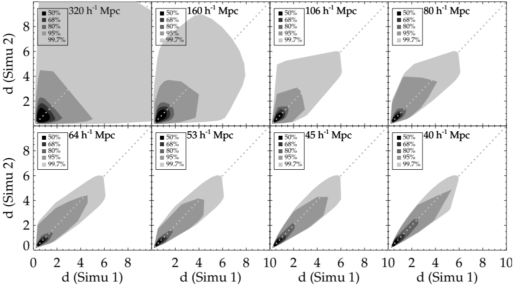
Random Simulations
(same seed)



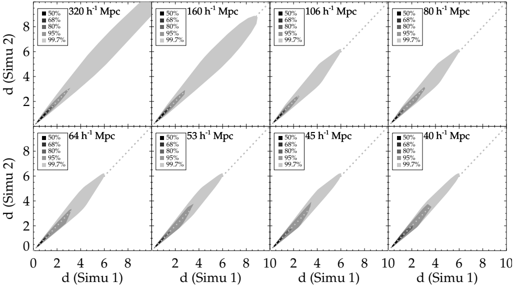
Constrained Simulations

Robust density field →
robust Large-Scale Environment to study local objects

Robust Large-Scale Environment



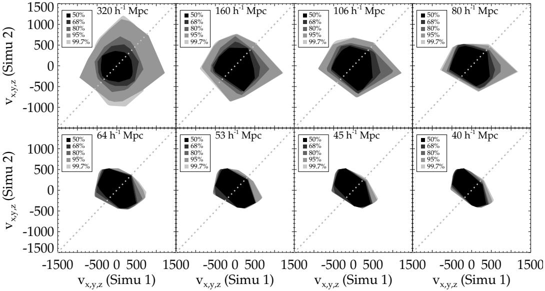
Constrained simulations
(different 'CR' seeds)



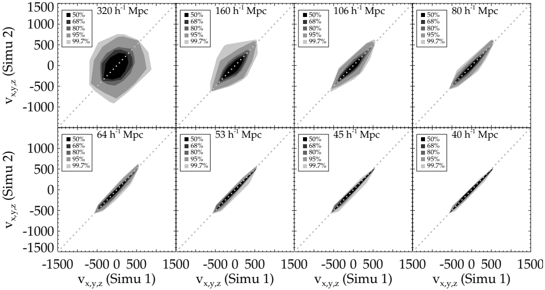
Constrained Simulations
(different 'Increasing Res.' seeds)

Robust density field →
robust Large-Scale Environment to study local objects

Robust Large-Scale Cosmic Flows



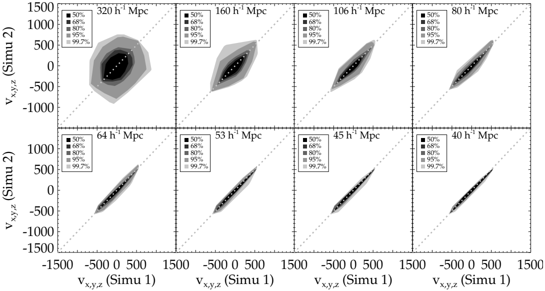
Random Simulations
(same seed)



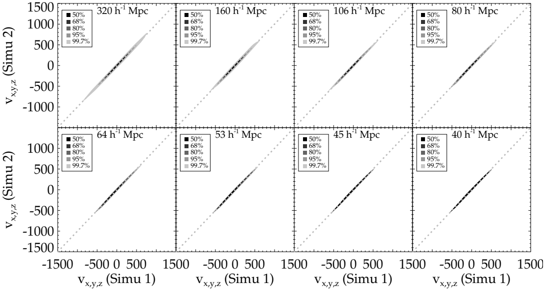
Constrained Simulations

Robust velocity field →
robust Large-Scale cosmic flows to study local objects

Robust Large-Scale Cosmic Flows



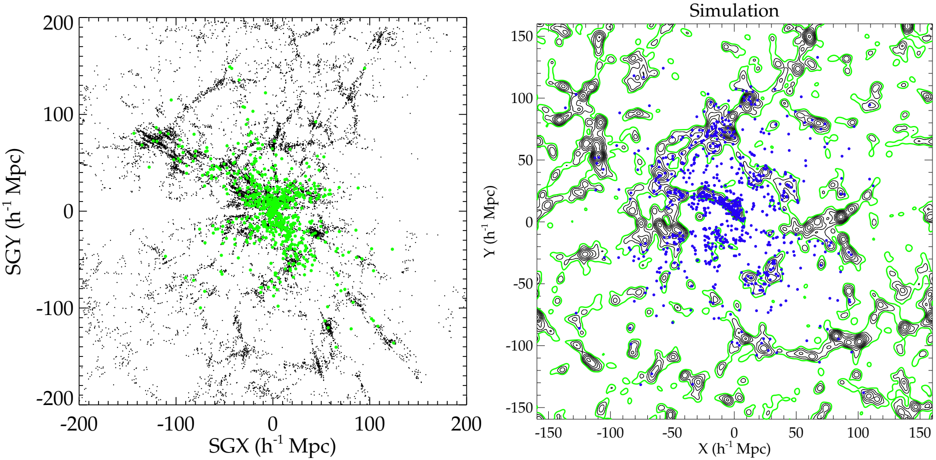
Constrained simulations
(different 'CR' seeds)

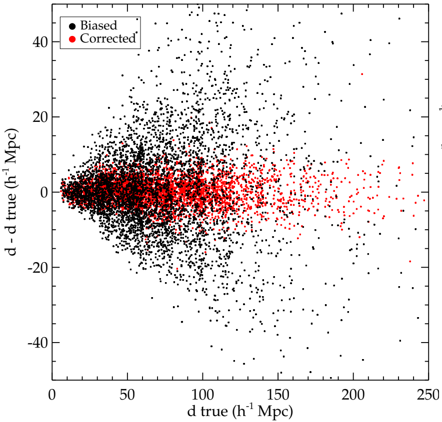


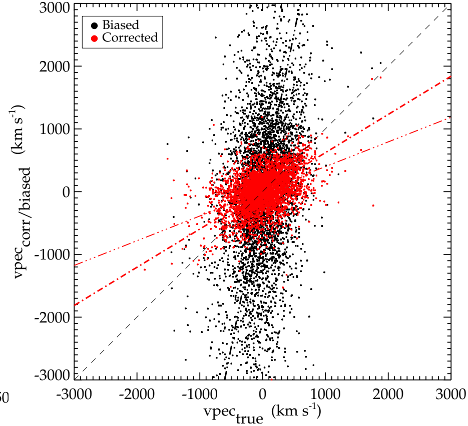
Constrained Simulations
(different 'Increasing Res.' seeds)

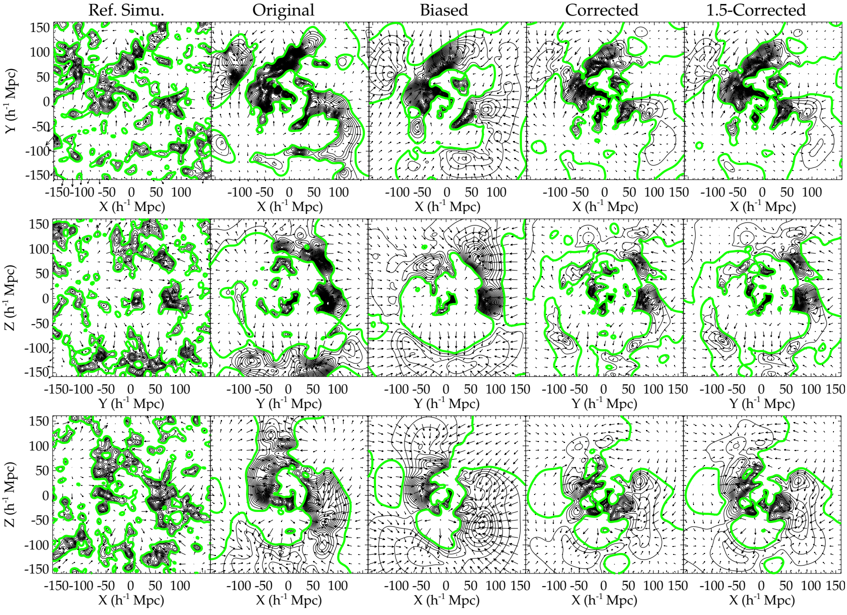
Robust velocity field $\rightarrow$ **robust Large-Scale cosmic flows to study local objects**

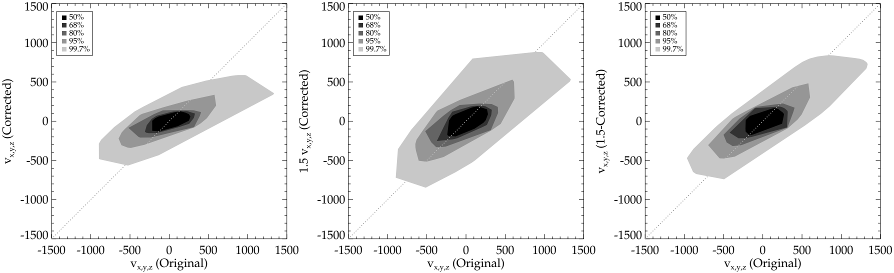
Figure Bias Paper

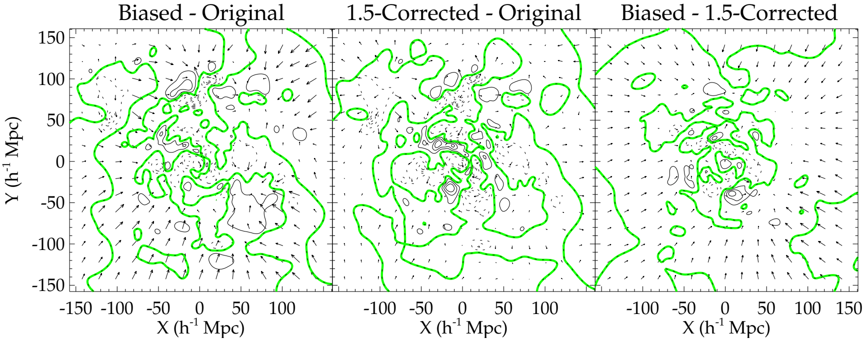



Biased
Corrected
40
20
0
-20
-40
0
50
100
150
200
250
d - d true (h-1 Mpc)
d true (h-1 Mpc)


Biased
Corrected
3000
2000
1000
0
-1000
-2000
-3000
vpec_corr/biased (km s-1)
vpec_true (km s-1)


Ref. Simu.
Original
Biased
Corrected
1.5-Corrected
Y (h-1 Mpc)
Z (h-1 Mpc)
X (h-1 Mpc)
Y (h-1 Mpc)
-150 -100 -50 0 50 100 150


50%
68%
80%
95%
99.7%
$v_{x,y,z}$ (Corrected)
$v_{x,y,z}$ (Original)
1.5 $v_{x,y,z}$ (Corrected)
$v_{x,y,z}$ (1.5-Corrected)
-1500 -1000 -500 0 500 1000 1500


Biased - Original
1.5-Corrected - Original
Biased - 1.5-Corrected
Y (h^{-1} Mpc)
X (h^{-1} Mpc)
-150 -100 -50 0 50 100 150

Before the conclusion - A little entertainment

Formation and Evolution of the Large Scale Structure of the Local Universe