CLUES to overcome Biases

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CLUES workshop

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IPNL / University of Lyon - AIP / University of Potsdam

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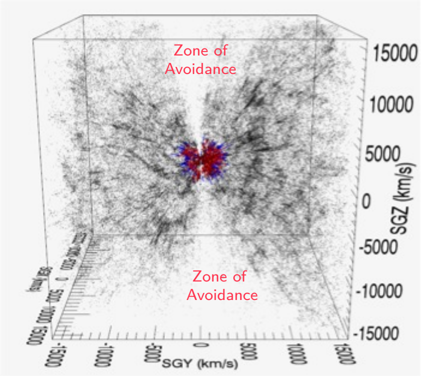
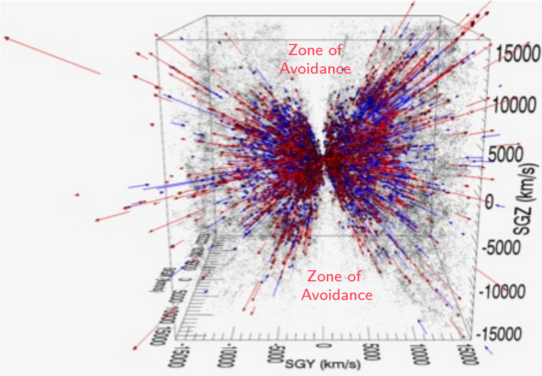
CF1 and CF2: Evolution of Cosmicflows Catalogs

Galaxies with measured radial peculiar velocities



Cosmicflows-1
about 2000 constraints
Tully et al. 2008



Cosmicflows-2
about 8000 constraints
Tully et al. 2013

With each catalog, improvements of :

- **quality** (*e.g. accuracy*)
- **quantity** (*e.g. farther, Zone of Avoidance*)

Black dots: XSCZ redshift catalog

How Catalogs Are Built

$$v_{obs} = H_0 \times \mathbf{d} + v_{pec\ radial} \quad (1)$$

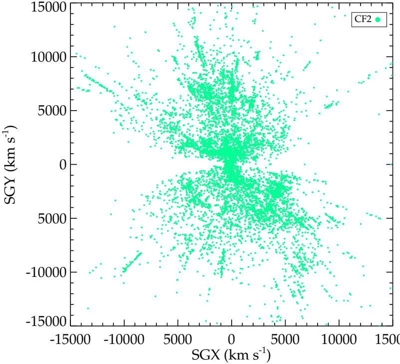
redshift constant distance velocity

$$m - M = 5log_{10}(\mathbf{d}(Mpc)) + 25 \quad (2)$$

$m \leftrightarrow$ **Photometry** — Observations

$M \leftrightarrow$ **ITFR** : $L \propto v_{HI}^{\alpha}$ — Calibrations

Mainly (Tully & Fisher 1977)

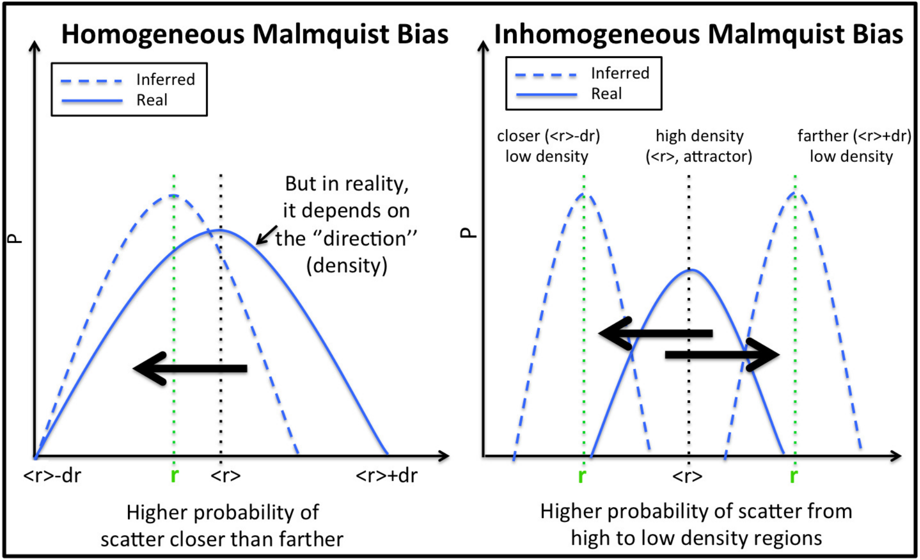


CF2

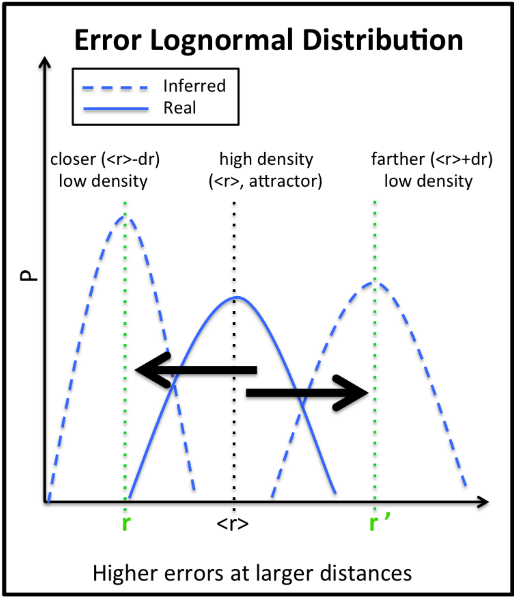
$\overset{(2)}{\hookrightarrow}$ **d** $\overset{(1)}{\rightarrow}$ radial v_{pec} $\rightarrow$ Cosmicflows Catalogs $\rightarrow$ e.g. CF1, CF2

$\Rightarrow$ **Constrained Simulations** methods, mocks, observational data

Deeper Catalogs CF2: Stronger Biases' Effects



Deeper Catalogs CF2: Stronger Biases' Effects



Error Lognormal Distribution:

Example:

μ=35±0.8 mag (20% on d) ⇒

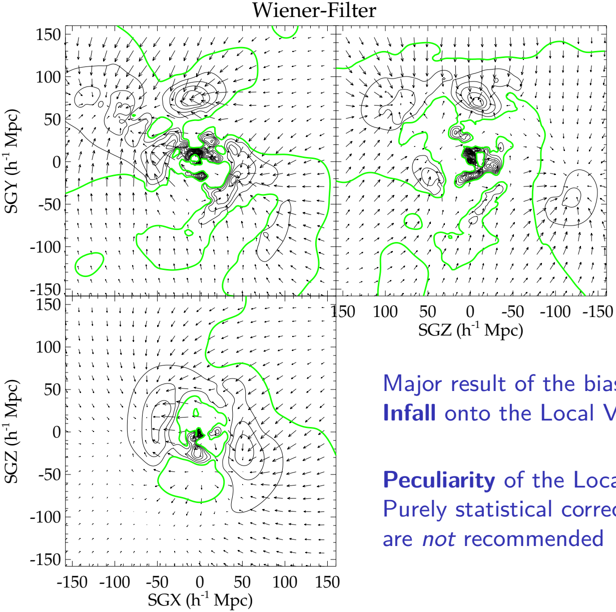
d=100 [69;145] Mpc (-31;+45)

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

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

Asymmetry

General **Infall** onto the Local Volume

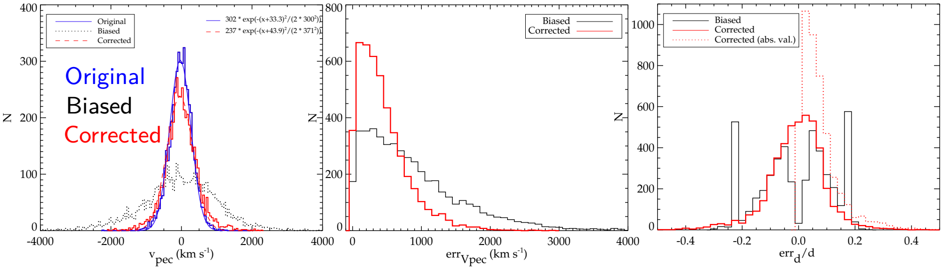


Major result of the biases: General **Infall** onto the Local Volume

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

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

Method 1: use of CF2-Mocks



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

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

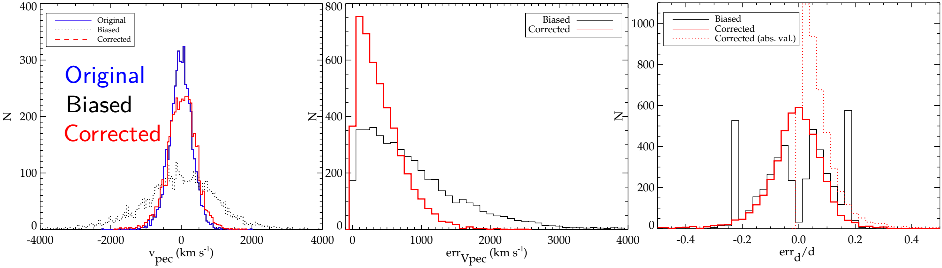
- p: probability $v_{pec} \notin$ theoretical Gaussian (from the mock) (Sheth and Diaferio, 2001)
- w: weighted uncertainty on v_{pec}

After correction:

- distances computed accordingly: $d_c = (v_{obs} - v_{pec\,c})/H_0$
- 5-6% fractional error on distances assumed.

Proposition of a Method to Minimize the Infall (Biases)

Method 2: use of the Wiener-Filter reconstructed velocity field



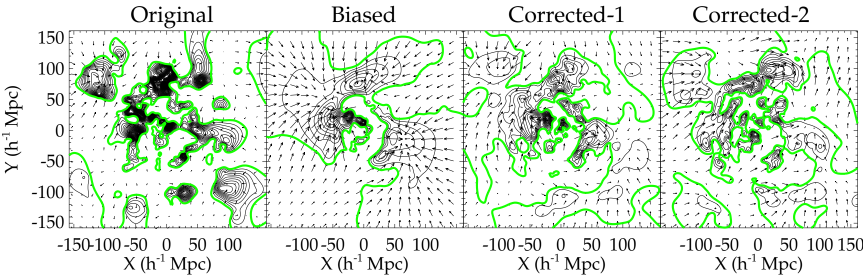
$$v_{pec\ c} = g \times v_{pec\ rad}^{WF} + (1 - g) \times v_{pec}$$

- g: chosen to minimize the monopole term ($\propto \vec{\nabla}.\vec{v}$) at 150 h^{-1} Mpc of the Wiener-Filter velocity field obtained after correction

After correction:

- distances computed accordingly: $d_c = (v_{obs} - v_{pec\ c})/H_0$
- 5-6 % fractional error on distances assumed.

Confirming Bias Correction on Mocks



Scatter from Cell-to-Cell comparisons between velocity fields

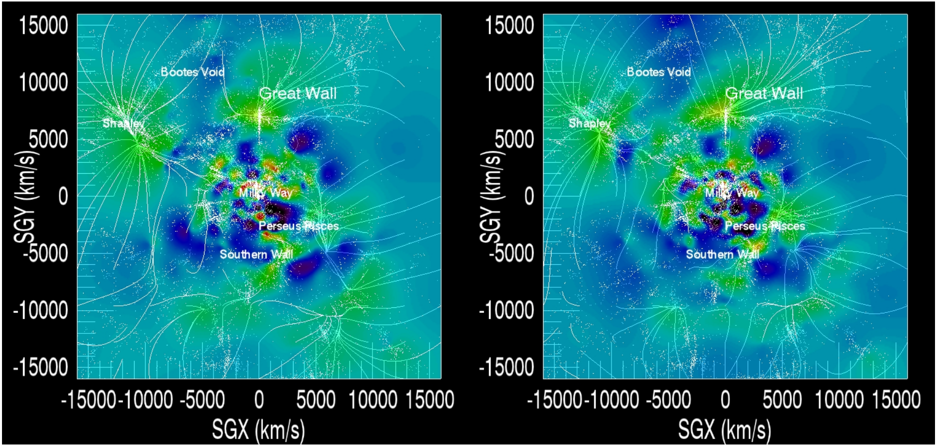
Mock	σ_{WF} km s^{-1}	σ_{WF} h^{-1} Mpc	σ_{simu} km s^{-1}	σ_{simu} h^{-1} Mpc	$\sigma_{WF\ div}$ km s^{-1}	$\sigma_{WF\ div}$ h^{-1} Mpc
Biased	182	3.8	220	4.5	195	4.
Corrected-1	116	2.4	149	3.1	129	2.7
Corrected-2	156	3.2	171	3.5	156	3.2

Comparison between methods:
- Full: σ=92 km s^{-1}(1.9 h^{-1} Mpc) $<$ 2 h^{-1} Mpc
- Div.: σ=67 km s^{-1}(1.4 h^{-1} Mpc) (linear theory)

Large Scale Structures, voids and flows of the reference simulation are robustly recovered with both methods at levels close to 3-4 h^{-1} Mpc .

Confirming Bias Correction with CF2

Method 1 Method 2

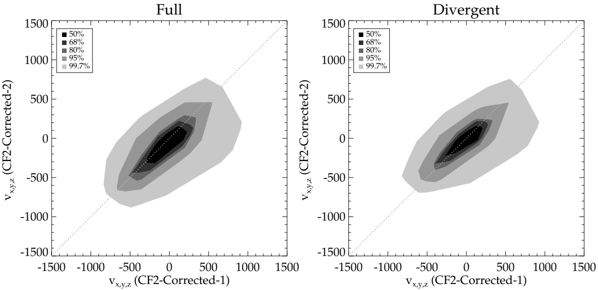


The Large Scale Structures and voids of the Local Universe are robustly recovered with both methods

White Dots = XSCZ redshift catalog

SDvision Software (Daniel Pomarède)

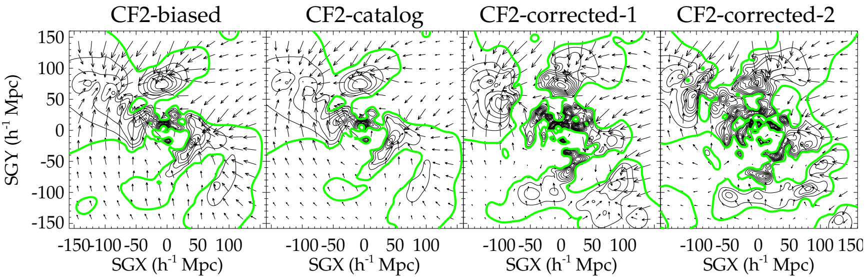
Consistency of the Two Corrective Methods



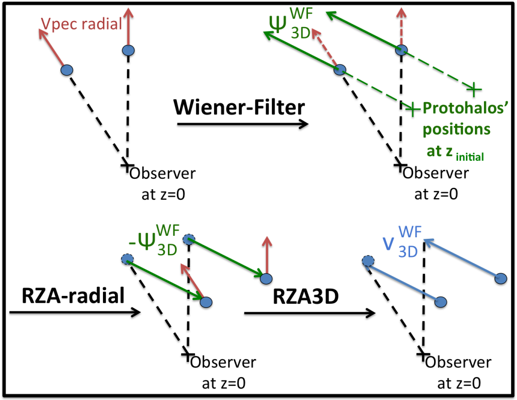
Scatter in terms of velocity: 58 / 48 km s^{-1}

leading to a scatter in terms of displacement: **1.2 / 1 h^{-1} Mpc**

$<$ 3 h^{-1} Mpc (linear theory + bias residual)



Reverse Zel'dovich Approximation



Reconstructions

Wiener-Filter (ΛCDM) *(Zaroubi et al. 1995)*

⇓

RZA3D *(Doumler et al. 2013a,b,c ; Sorce et al. 2014)*

⇓

Constrained Realizations (ΛCDM)

(Hoffman & Ribak 1991)

⇓

Initial Conditions

⇓

Constrained Simulations

Reverse Zel'dovich Approximation:

$$\vec{x}_{init}^{RZA} = \vec{r} - \frac{\vec{v}}{H_0 \; f(t_{init})}$$

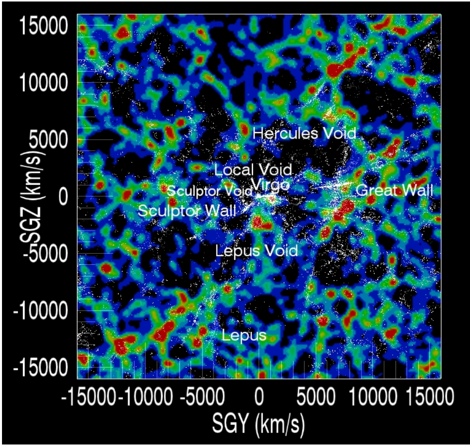
$$\text{growth rate} : f(t) = \frac{d\;(ln\;D(t))}{d\;(ln\;a(t))} \quad \frac{\text{growth factor}}{\text{scale factor}}$$

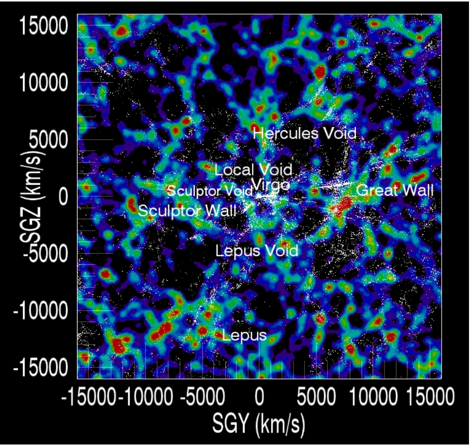
Linear Theory at 1st order valid down to 2 h^{-1} Mpc

Formation of Structures: A Movie

At $z = 0$,

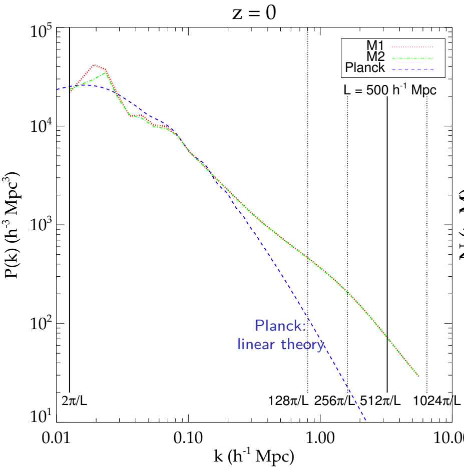
Method 1 Method 2

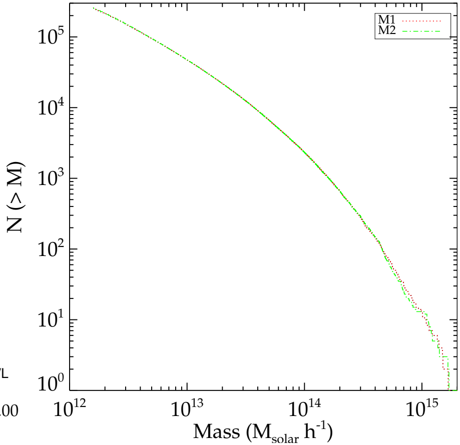




Periodic Boundary Conditions, L=500 h^{-1} Mpc , $n^3=512^3$

Validation of Second Generation Constrained Simulations





Replicas of Virgo

Method 1 correction ≈ 0.5 σ
Method 2 correction ≈ 2 σ → less credit to observational measurement

Virgo	SGX	SGY	SGZ	$v_{pec\ rad}$	v_{pec}	d	M	δ_x	δ_y	δ_z	δ_{tot}
Observed	-2.80	12.0	-0.561	207	/	12.3	40†				
Corrected M1	-2.79	11.9	-0.559	207		12.3	/				
Inserted in CR M1	2.82	9.90	-1.02	/	311		/				
Corrected M2	-2.73	11.7	-0.547	232		11.4	/				
Inserted in CR M2	-1.46	9.63	4.70	/	280		/				
	-6.61	10.93	-2.42	224	472	13.0	1.8	-3.81	-1.05	-1.86	4.37
Simulated	-4.15	9.02	2.64	145	562	10.3	1.4	-1.34	-2.95	3.21	4.56
	-5.43	9.61	-3.74	345	489	11.7	1.0	-2.63	-2.36	-3.17	4.75
M1											
	0.27	11.16	-1.15	48	440	11.2	4.9	3.07	-0.82	-0.59	3.23
σ	3.01	1.03	2.75	125	51	1.13	1.8	3.01	1.03	2.75	0.68
Simulated	-3.42	10.3	-4.93	237	311	11.9	1.1	-0.69	-1.41	-4.38	4.66
	-3.18	7.18	-1.28	392	421	7.96	1.4	-0.45	-4.52	-0.73	4.60
M2	-5.57	13.5	1.61	291	385	14.7	1.7	-2.84	1.48	2.16	3.98
	-5.99	14.0	0.334	277	384	15.2	1.7	-3.26	1.99	0.88	4.07
σ	1.45	3.15	2.83	66	46	3.31	0.30	1.45	3.15	2.83	0.35

Robust Large-Scale Environment

Method 1
(five simulations)

Method 2
(five simulations)

Virgo region ?

Virgo region ?

Major Attractors and Voids of the Local Universe are **simulated repetitively**
↪ **robust Large-Scale Environment to study local objects**

Robust Large-Scale Environment

Method 1
(five simulations)

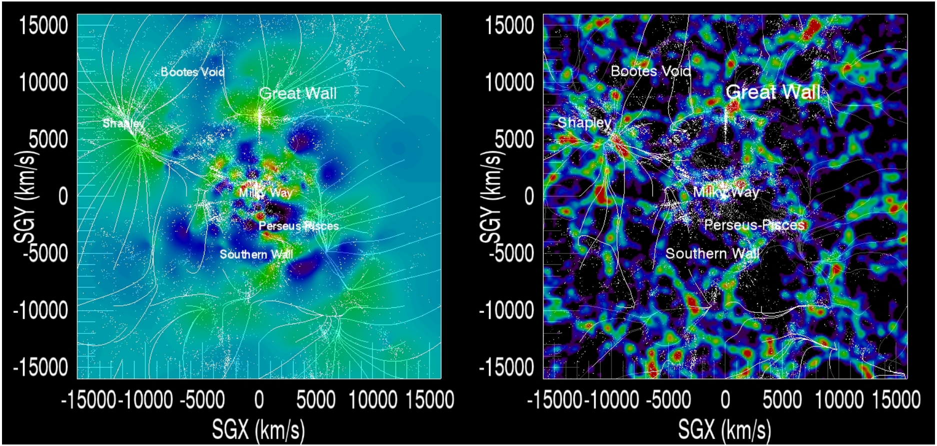
Method 2
(five simulations)

Virgo region $\surd$

Virgo region X

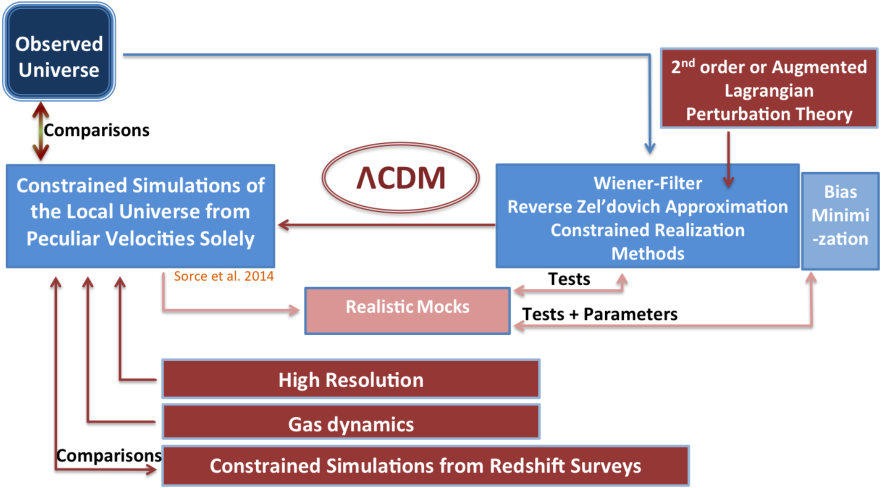
Major Attractors and Voids of the Local Universe are **simulated repetitively**
$\hookrightarrow$ **robust Large-Scale Environment to study local objects**

Comparisons Observations/Reconstructions/Simulations



Observation/Reconstruction/Simulation

Overview and Prospectives



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