Reconstructing the Density and Peculiar Velocity Fields

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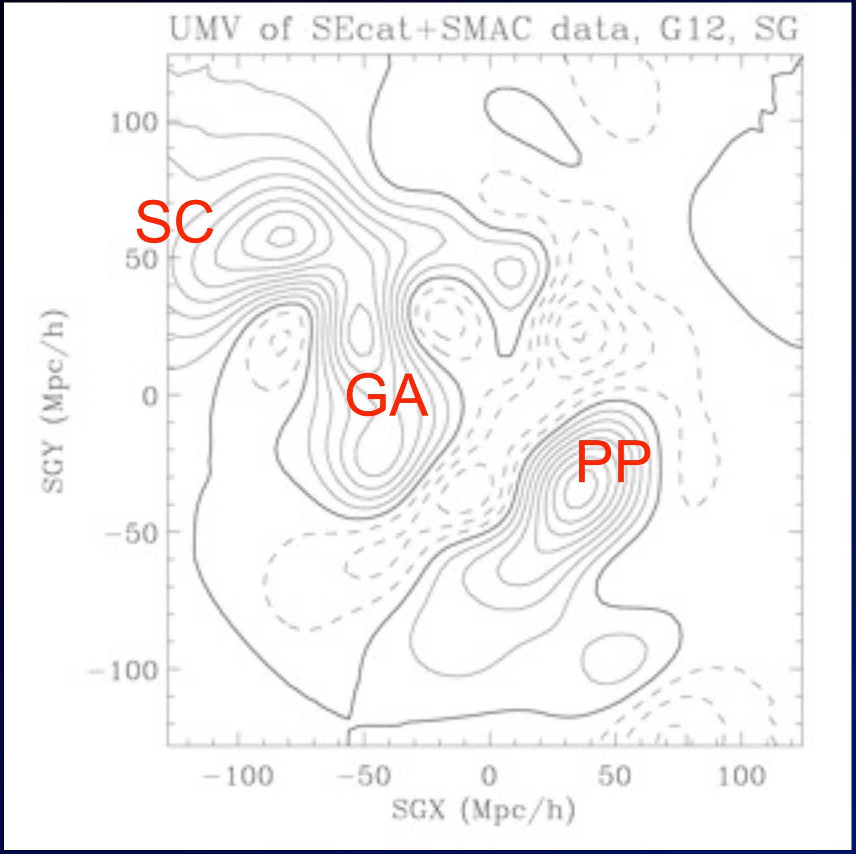
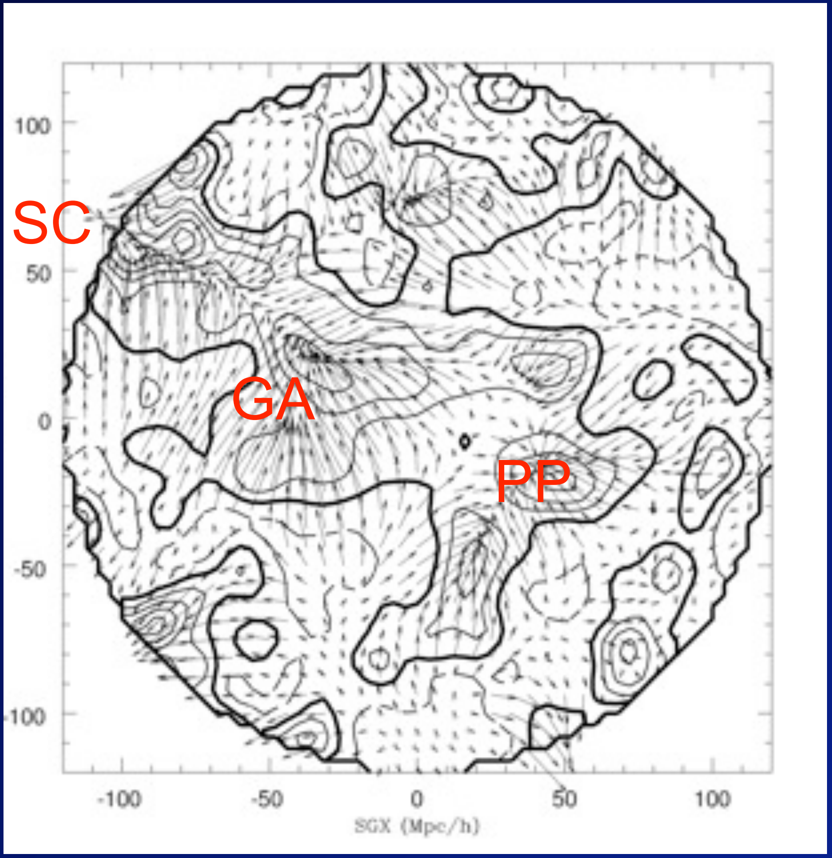
Mass vs Light



Mass (Zaroubi)
Inversion of peculiar velocity field



(Far-infrared) Galaxy Light
(PSCz : Branchini)

Peculiar Velocities and Gravity

$$v = cz - H_0 r$$

$$\mathbf{v}(\mathbf{r}) = \frac{\Omega_m^{0.55}}{4\pi} \int d^3\mathbf{r}' \delta_m(\mathbf{r}') \frac{(\mathbf{r}' - \mathbf{r})}{|\mathbf{r}' - \mathbf{r}|^3}$$

In linear perturbation theory, peculiar velocity is proportional to peculiar acceleration

$$v(r) = \frac{\Omega^{0.6} H_0}{4\pi} \int \delta(r') \frac{(r' - r)}{|r' - r|^3} d^3 r'$$

- Use galaxy $\delta_g = b\,\delta$
- Model external flows as bulk flow

$$v(r) = \frac{\Omega^{0.6}}{b} \frac{1}{4\pi} \int^{R_{max}} \delta_g(r') \frac{(r' - r)}{|r' - r|^3} d^3 r' + \vec{U}$$

Reconstruction

1. From galaxies to mass density

2. From redshift-space to real space

From galaxies to mass density

Assume galaxies are Poisson-sampled from underlying density field

Weight galaxies by inverse of selection function

Can we do better?

- Halo model
- Q: Given a set of haloes with M>M_lim what is the bets way to reconstruct the density map

Iterative methods

Raw data in density in redshift-space, we want density in *real* space

1. Use linear theory to calculate peculiar velocities
2. Correct redshifts by peculiar velocity to get distance
3. Update determination of LF, selection function and weights
4. Go to 1

“Adiabatic” method: slowly increase β at each step

How well does it work?

For an ideal survey:

<100 km/s difference between v and v_pred, depending on density

For IRAS Monte Carlo simulations

~100-200 km/s depending on distance

Davis, Strauss and Yahil 1991

But empirically VELMOD fits compared to IRAS

~125 km/s

Willick, Strauss et al 98.

Comparing unsmoothed velocities to smoothed predictions

What smoothing is best?

~4 Mpc/h Gaussian

Berlind, Narayanan, Weinberg et al 2000

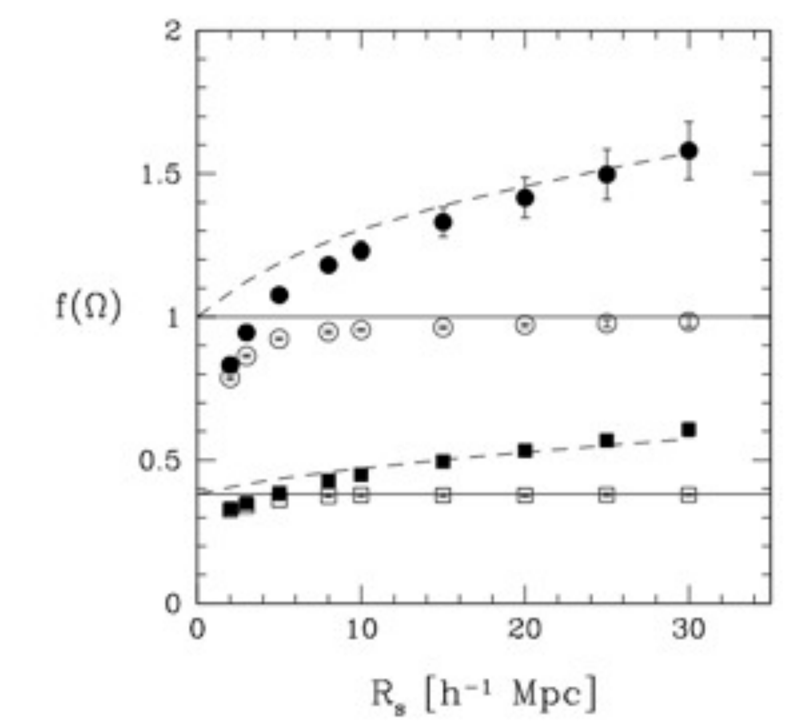
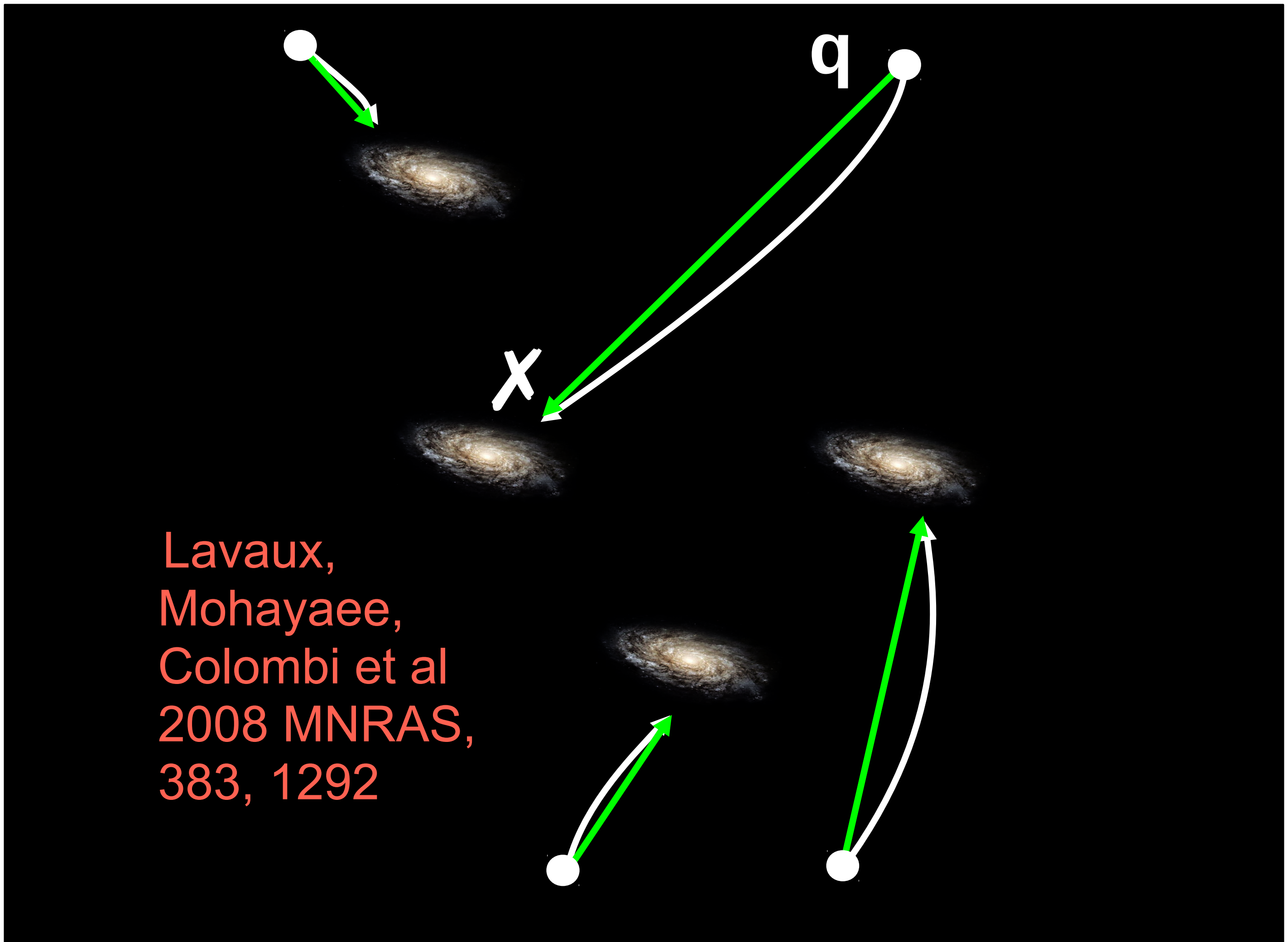


FIG. 2.—Estimates of $f(\Omega_m)$ from the slope of the relation between true galaxy velocities and velocities predicted by linear theory from the smoothed density field, as a function of the smoothing radius, R_s, for CDM models with $\Omega_m = 1$ (*circles*) and 0.2 (*squares*). Points represent the mean result of four simulations of each model, and error bars show the uncertainty in the mean derived from the dispersion among the simulations. Filled symbols show the estimated $f(\Omega_m)$ when the density field is smoothed with a Gaussian filter of radius R_s. Open symbols show the estimated $f(\Omega_m)$ when the density field is smoothed with a sharp low-pass k-space filter (with a cut at k_{cut}), where R_s is the radius of a Gaussian filter that falls to half its peak value at $k = k_{cut}$. Dashed lines show the linear-

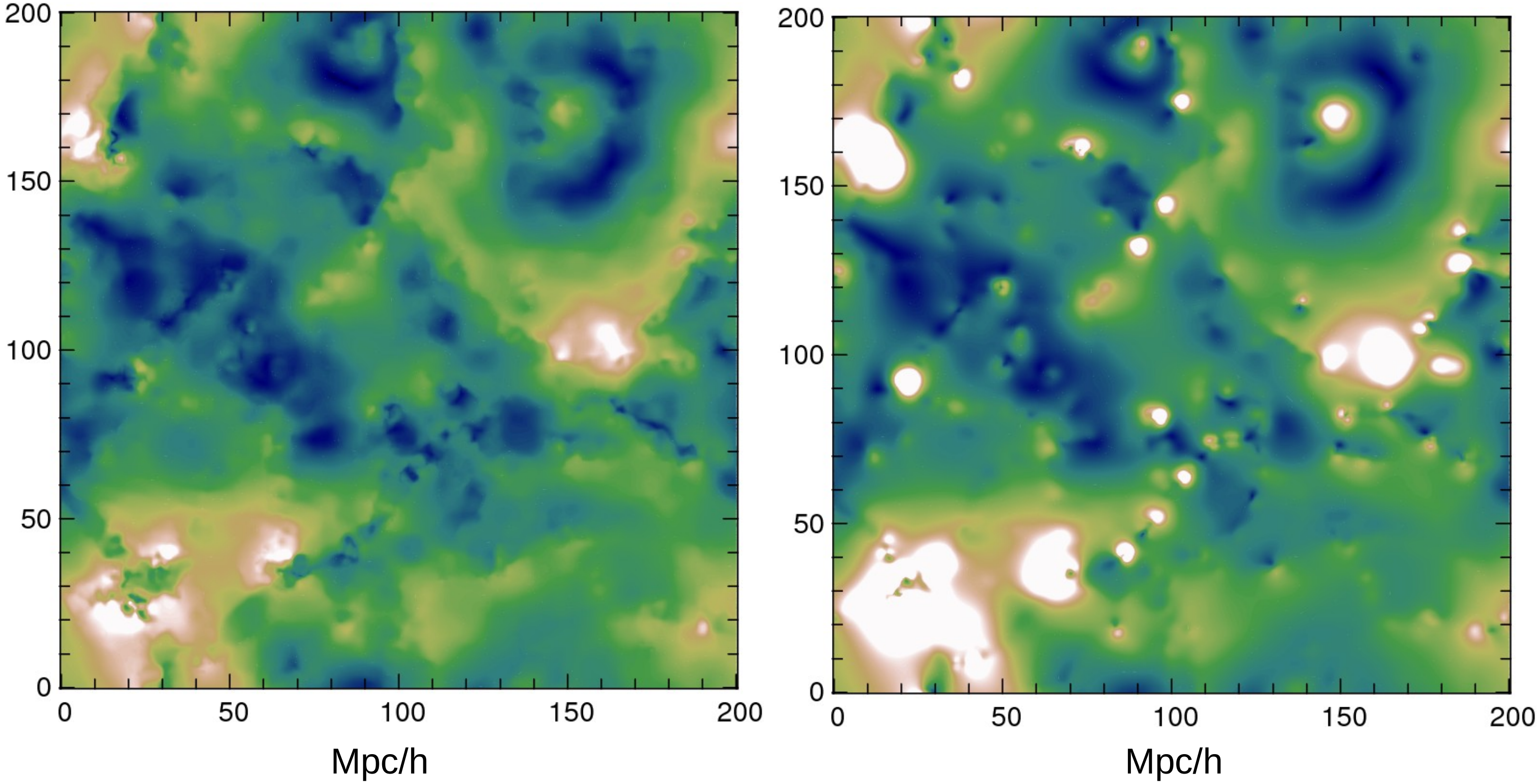
The MAK reconstruction

The MAK displacements



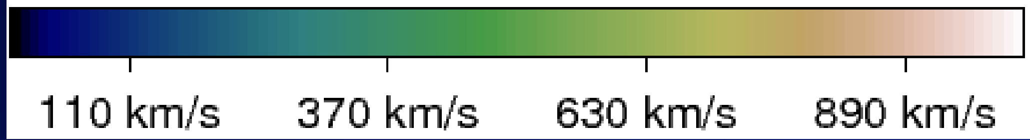
Comoving coordinates

Test on N-body simulations

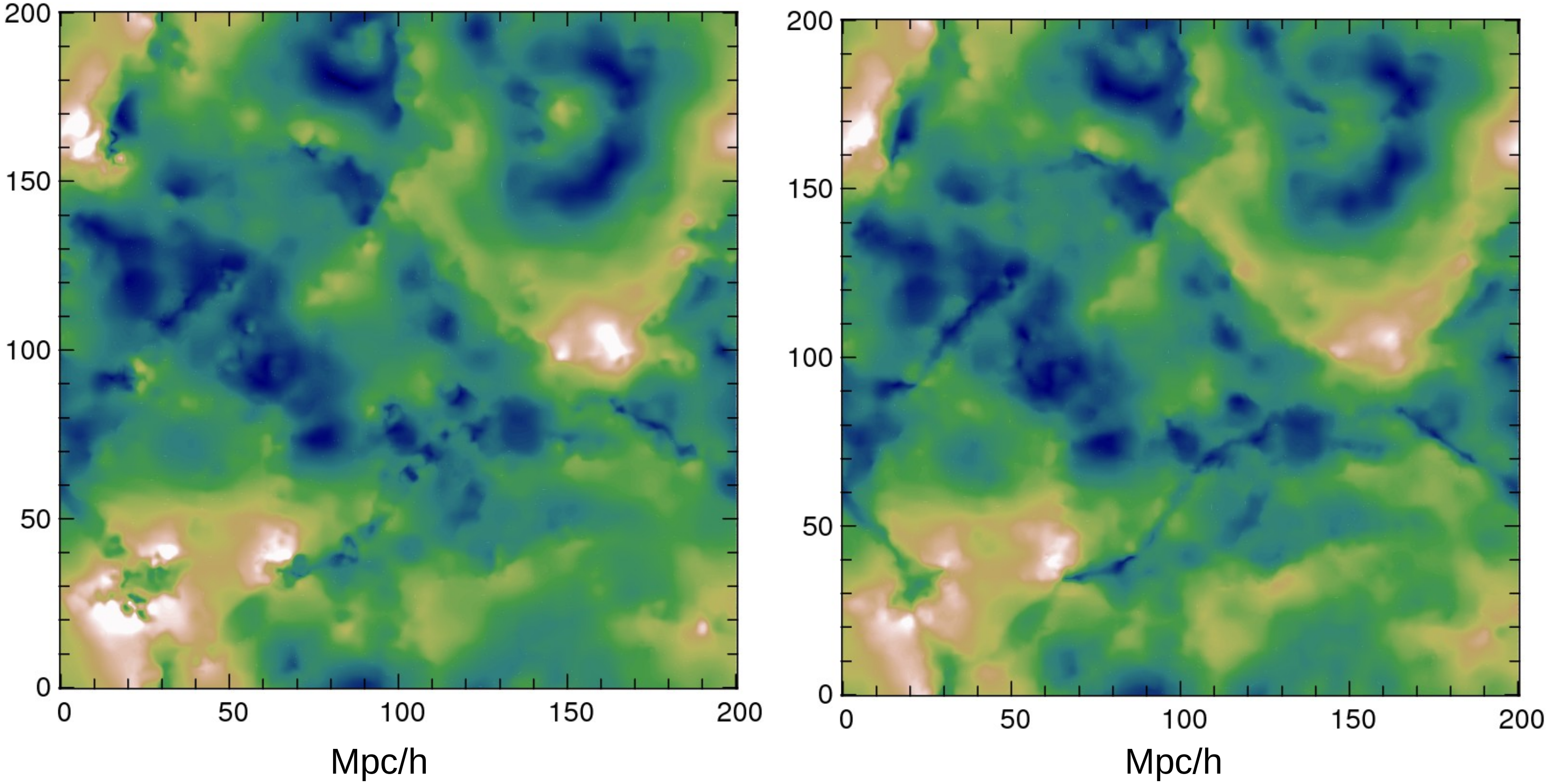


Simulated velocity field

Reconstructed velocity field
(**linear theory**)

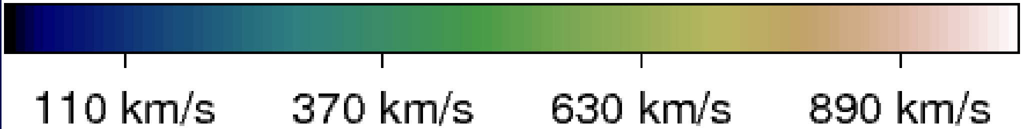


Test on N-body simulations



Simulated velocity field

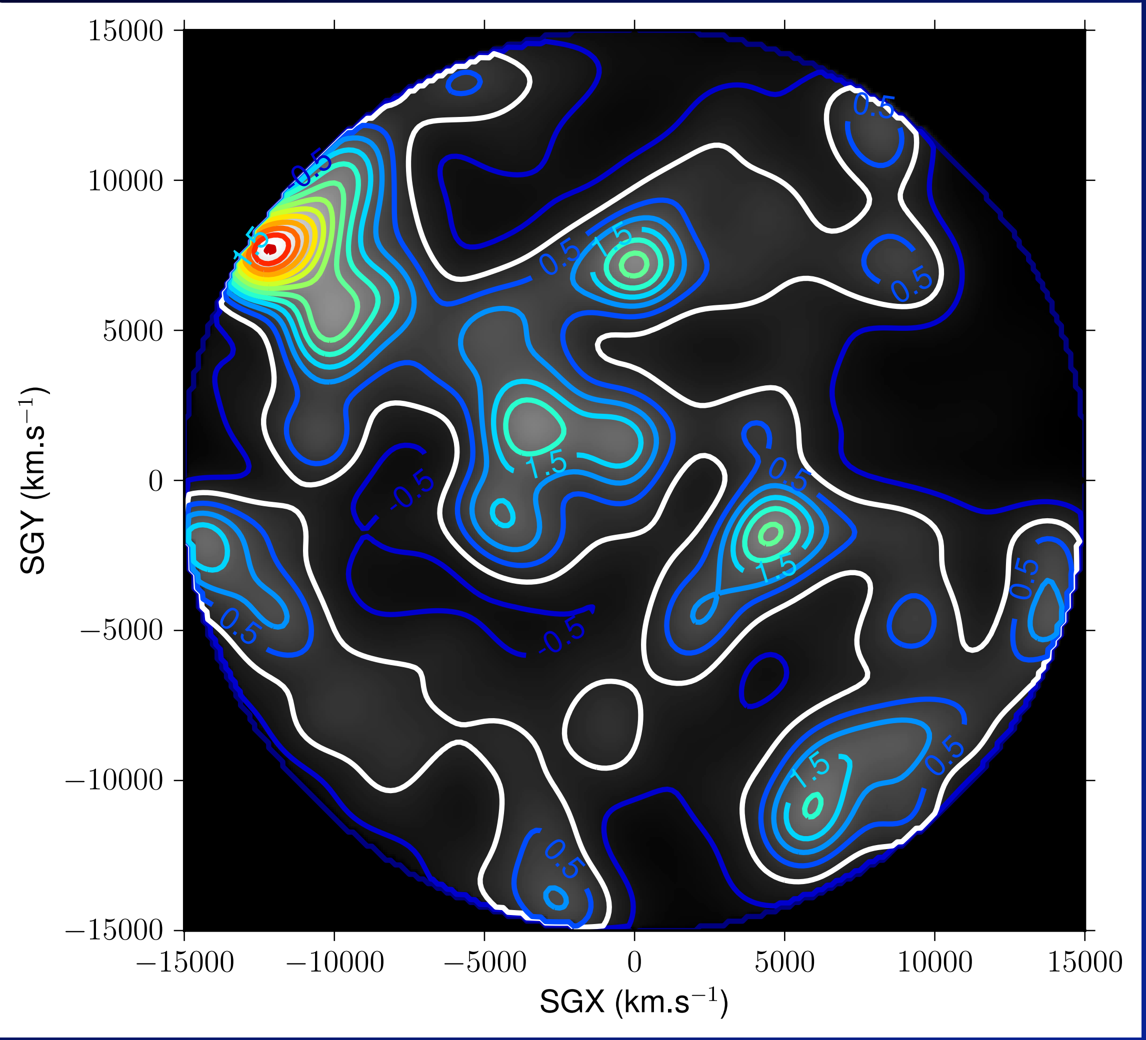
Reconstructed velocity field
(**MAK reconstruction**)



New Density Maps

2M++
6dFGS and
SDSS
extend
2MRS

Lavaux &
Hudson 2011



Tests of Beta

Berlind, Narayan, Weinberg 2001

TABLE 2

ESTIMATES OF β FROM THE BIASED MODELS, USING DIFFERENT TECHNIQUES

		β_{est}			
MODEL (1)	β_{σ} (2)	POTENT (3)	VELMOD (4)	$P^S(k)/P^R(k)$ (5)	$P_2(k)/P_0(k)$ (6)
$\Omega = 1.0$					
Mass	1.00	0.92	0.94	0.80	0.93
Semianalytic	0.61	0.61	0.56	0.54	0.57
Sqrt-exp.	0.62	0.84	0.69	0.64	0.98
Power-law	0.60	0.60	0.57	0.52	0.55
Threshold	0.57	0.55	0.56	0.47	0.55
Sigma	0.54	0.53	0.56	0.46	0.52
Sheet	0.66	0.53	0.44	0.46	0.52
High-*z*	0.60	0.58	0.55	0.52	0.58
$\Omega = 0.4$					
Mass	0.58	0.56	0.54	0.50	0.64
Semianalytic	0.57	0.55	0.54	0.49	0.59
Sqrt-exp.	0.77	0.93	0.80	0.69	0.76
$\Omega = 0.2$					
Mass	0.38	0.36	0.35	0.32	0.43
Semianalytic	0.52	0.46	0.48	0.41	0.51
Sqrt-exp.	0.66	0.71	0.64	0.59	0.57
Power-law	0.54	0.49	0.48	0.45	0.52

NOTE.—POTENT results are shown for a 12 h^{-1} Mpc Gaussian smoothing. VELMOD results are shown for a 3 h^{-1} Mpc Gaussian smoothing. For $\Omega_m = 1.0$, all uncertainties are ~0.005. For low Ω_m, uncertainties are ~0.002, except for sqrt-exp models, where they are ~0.04 for $\Omega_m = 0.4$ and ~0.02 for $\Omega_m = 0.2$.

Reconstructing mass density from peculiar velocities only

- POTENT
- Weiner filter
  - biases density low
- Unbiased minimum variance method
  - Zaroubi et al 2002

To Do List

- New end-to-end simulations
- Beyond the halo model ... ?
- Improved non-linear corrections .... ?
- Solve the problem of triple valued regions ... ?