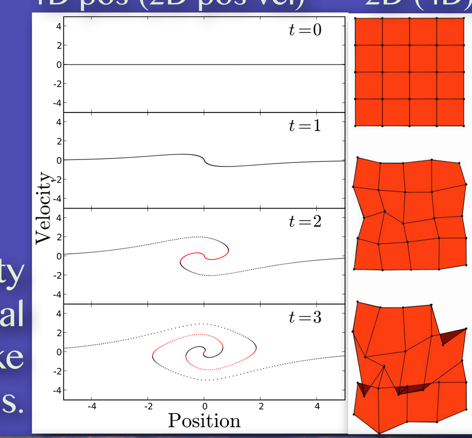
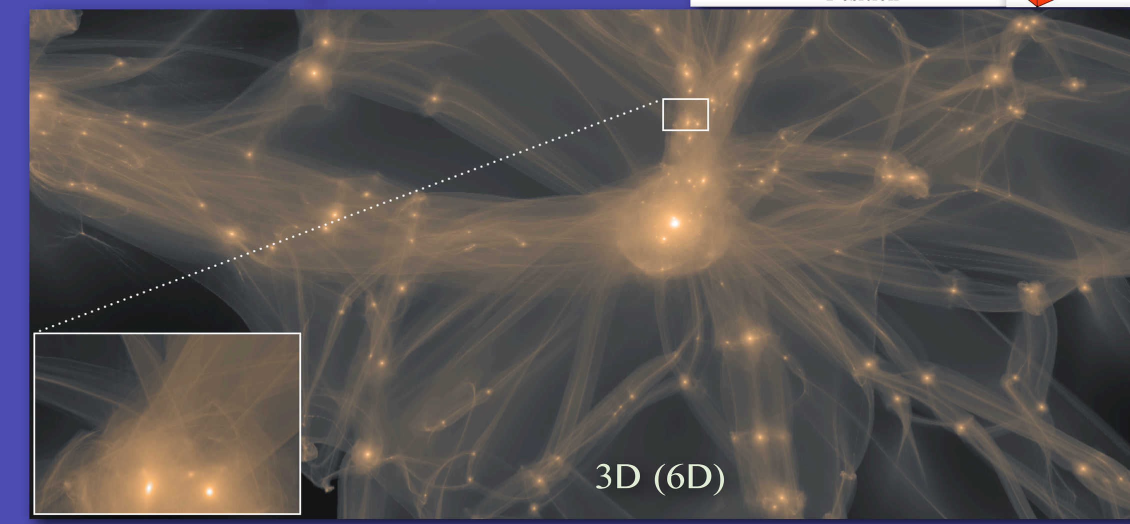
The Origami Dynamics of the Dark-Matter Sheet and Improved Cosmological Constraints from Understanding It

Mark Neyrinck
Nuala McCullagh
Alex Szalay

Johns Hopkins University

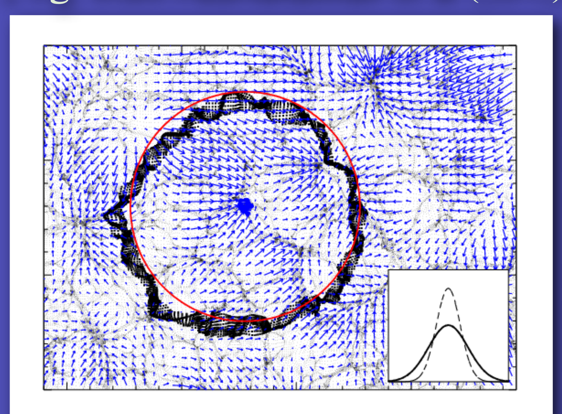


In position-velocity phase space, the initial dark-matter sheet folds up like origami to build structures.



↑ Fig. from Kaehler, Hahn & Abel (2012)

↓ Fig. from Padmanabhan et al. (2012)

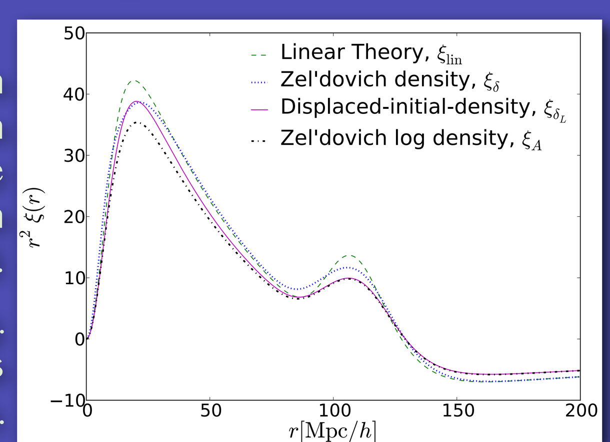


Matter flows around with ~10 Mpc displacement from its initial comoving location.

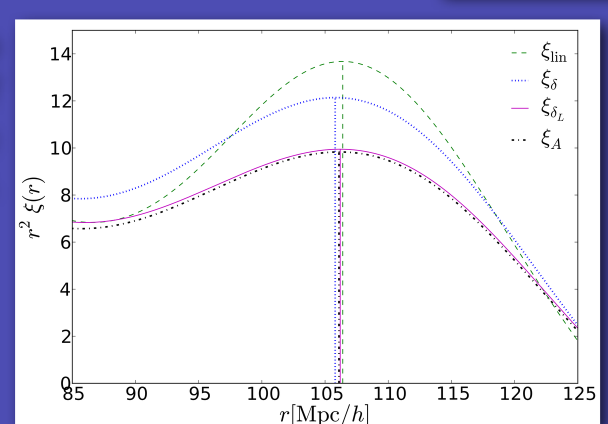
Around overdensities, BAO shells contract and get denser; around underdensities, BAO shells expand and get less dense.

The usual mass-weighted correlation function $\xi_\delta(r)$ weights overdensities more than underdensities. Because gravity pulls overdense BAO shells toward their overdense centers, on average the BAO peak is shifted a bit inward.

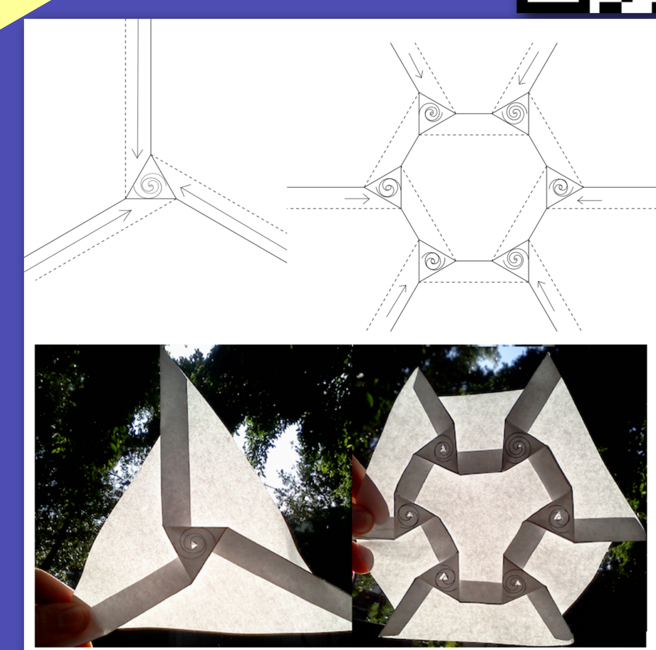
Try initial-density weighting instead of mass weighting. For example, boost the weight of underdense regions with a "Gaussianizing" logarithm, $\delta \to A = \log(1+\delta)$.



This largely removes the BAO shift, making the location of the peak of $\xi_A(r)$ more faithful to its initial location.

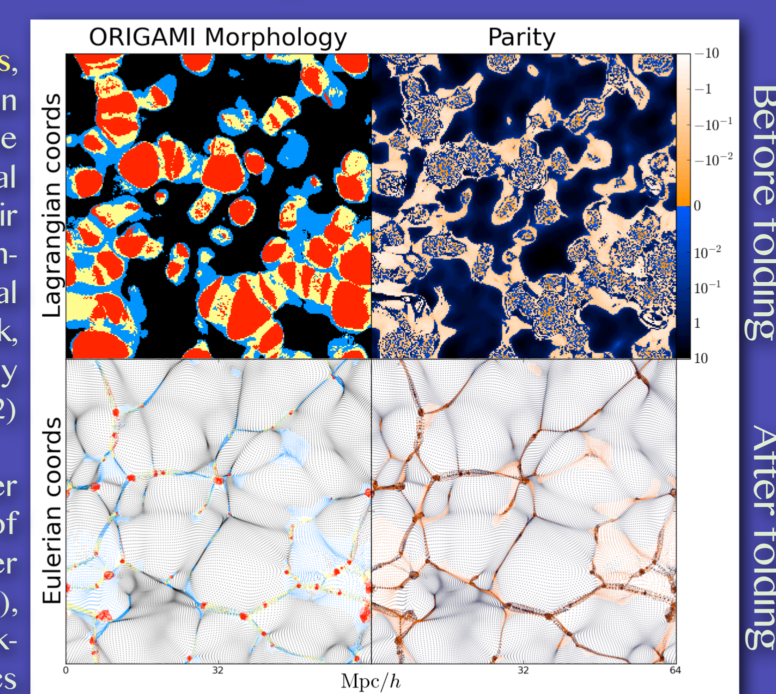


McCullagh, Neyrinck & Szalay (2013)



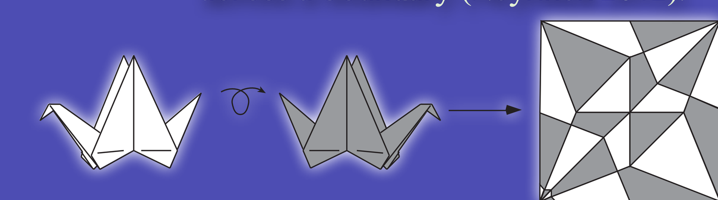
Download this poster/crease pattern, and other, simpler ones: http://skysrv.pha.jhu.edu/~neyrinck/origalaxies.html

The "crease pattern of the universe"



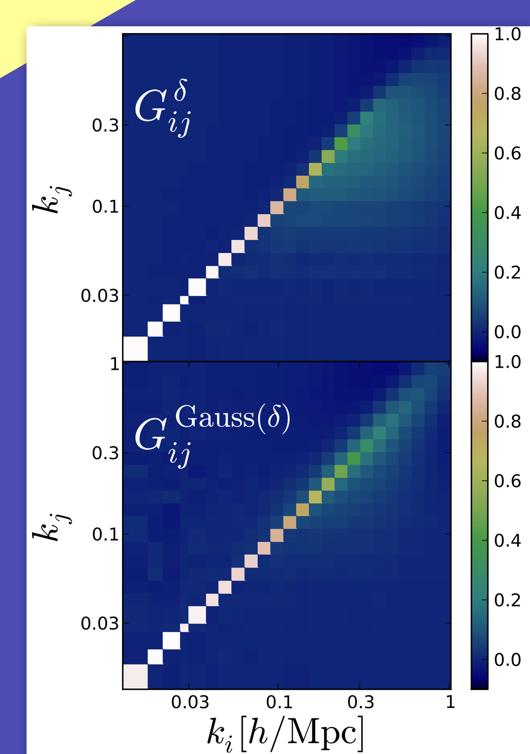
Haloes, filaments, walls and voids can be identified by the number of orthogonal axes along which their particles cross compared to the initial conditions (Falck, Neyrinck & Szalay 2012)

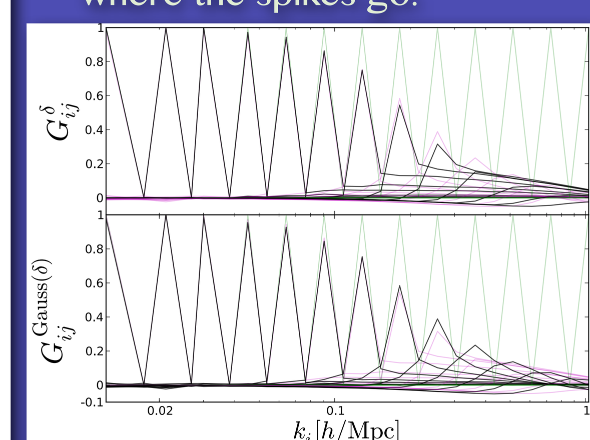
Like 2D flat paper origami, the graph of 3D dark-matter streams (polygons), bordered by dark-matter caustics (folds), is colorable with only 2 colors, without duplicating a color across a boundary (Neyrinck 2012).



2D flat origami is 2-colorable: "up" and "down" colors

In the usual matter power spectrum, power transfers from large to small scales (e.g. HKLM 1991, Peacock & Dodds 1996). This motion comes from over-weighting dense regions that contract. In the PDF-Gaussianized field, regions that grow less dense, and expand, are counted, too, so power moves both up and down in scale. This can be investigated by putting spikes at different wavenumber k in the initial conditions, and seeing where the spikes go.





At left is shown the linear-power-propagation matrix G_{ij} estimated from simulations:

$$P_j^{\rm nonlinear} = \sum_i G_{ij} P_i$$

Indeed, the spread of power is smaller and more symmetric in the Gaussianized field. (Neyrinck, in prep)

Sim. details: 512 Mpc/h boxsize, 512^3 particles, ALPT realizations (Kitaura & Hess 2013, see also Neyrinck 2013)

We acknowledge generous support from a New Frontiers grant from the John Templeton Foundation.

References:

Falck, Neyrinck & Szalay, 2012, ApJ, 754, 126, arXiv:1201.2353
Kaehler, Hahn & Abel, 2012, arXiv: 1208.3206
Hamilton et al., 1991, 374, L1
McCullagh, Neyrinck & Szalay, ApJL, 763, L14, arXiv: 1211.3130
Neyrinck 2012, MNRAS, 427, 94, arXiv: 1202.3364
Neyrinck 2013, MNRAS, 428, 141, arXiv: 1204.1326
Padmanabhan et al., 2012, MNRAS, 427, 2132
Peacock & Dodds, 1994, MNRAS, 280, L19