Unveiling the Initial Conditions and the Cosmic Structure of the Universe

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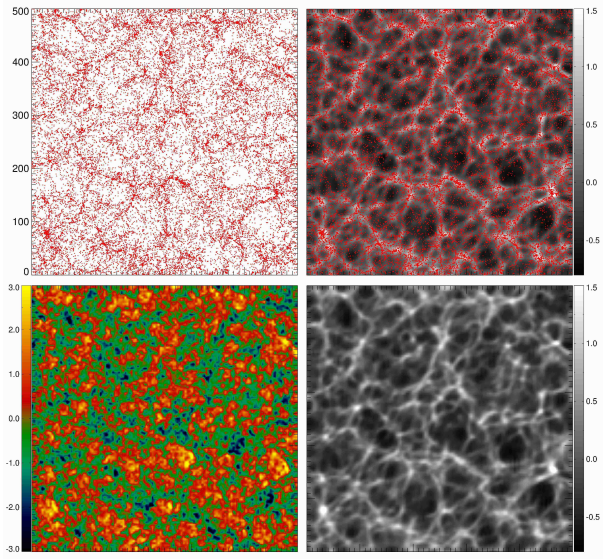
KIGEN: a Machine Learning Algorithm

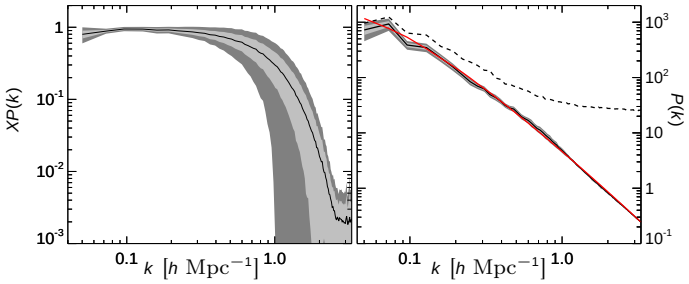
KIGEN is based on a new approach to recover the initial conditions and the cosmic web structure underlying a galaxy distribution (K13). The method uses a Bayesian Networks algorithm sampling Gaussian fields which are compatible with a galaxy distribution and a structure formation model (see K12). This is achieved by splitting the inversion problem into two Gibbs-sampling steps: the first being a Gaussianisation step transforming a distribution of point sources at Lagrangian positions –which are not a priori given– into a linear alias-free Gaussian field. The second step consists on a matching procedure in which the set of matter tracers at the initial conditions is constrained on the galaxy distribution and the structure formation model we assume. We use the efficient one-step solver given by second order Lagrangian Perturbation Theory (KA12;KAHG12).



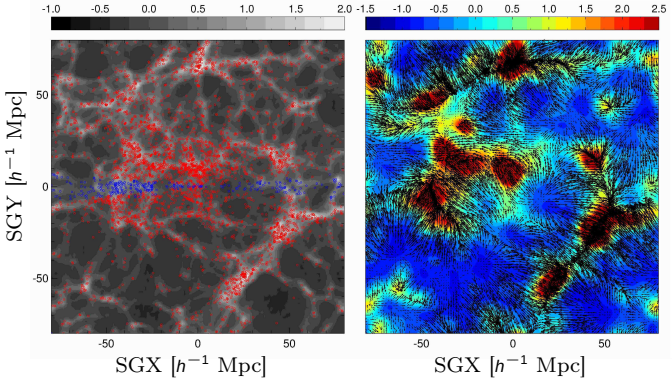
Upper left panel: slice about 4 h^{-1}Mpc thick averaged over 9 neighbouring slices through a catalogue of about 530 000 mock galaxies in a volume of 500 h^{-1}Mpc side (red circles). *Upper right panel:* same slice through a sample after 1000 iterations showing the reconstructed nonlinear matter density field using 384^3 particles gridded on a 128^3 mesh with triangular shape cloud. The mock galaxies corresponding to the same slice are over-plotted indicating the accuracy of the reconstruction method. *Lower left panel:* same slice through the reconstructed initial conditions corresponding to the same sample which are Gaussian distributed. *Lower right panel:* same as upper right panel without the mock galaxies.

Cosmic Structure of the Local Universe

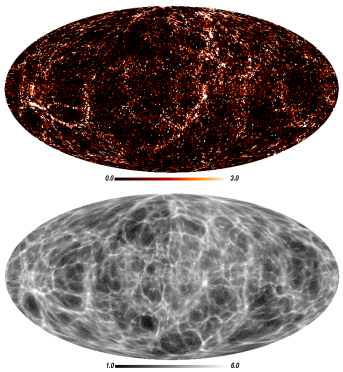
We present a cosmography analysis of the Local Universe based on the recently released Two-Micron All-Sky Redshift Survey (2MRS) using the KIGEN-code (KetalG12). From the ensemble of cross-correlations between the reconstructions and the galaxy field and the variance of the recovered density fields we find that our method is extremely accurate up to $k \sim 1\,h\,\mathrm{Mpc}^{-1}$and still yields reliable results down to scales of about 3-4 h^{-1} Mpc. The motion of the local group we obtain within $\sim 80\ h^{-1}$ Mpc ($v_{\rm LG} = 522 \pm 86$ km s^{-1}, $l_{\rm LG} = 291^\circ \pm 16^\circ$, $b_{\rm LG} = 34^\circ \pm 8^\circ$) is in good agreement with measurements derived from the CMB and from direct observations of peculiar motions and is consistent with the predictions of ΛCDM.



Left panel: Normalised cross-power spectra $XP(k) \equiv \langle|\delta^{\rm rec}(\boldsymbol{k})\delta^{\rm gal}(\boldsymbol{k})|\rangle/(\sqrt{P^{\rm rec}(k)}\sqrt{P^{\rm gal}(k)})$ between the galaxy overdensity and the reconstructed density field. *Right panel:* power spectrum of the galaxy field $P^{\rm gal}(k)$ (dashed curve), linear ΛCDM power spectrum (red curve), mean of the 100 reconstructed linear power-spectra of the initial field (black curve). The 1 and 2 sigma contours are light and dark shaded regions, respectively.



Supergalactic XY-plane (SGZ=0) with $\sim$20 h^{-1} Mpc thickness of a 128^3 grid with 160 h^{-1} Mpc side (resolution of 1.25 h^{-1} Mpc): *left panel*: logarithm of the reconstructed density field $\ln(2 + \delta^{\rm rec})$ with overplotted observed galaxies in red and augmented ones in blue; *right panel*: $v_x - v_y$ velocity field with the underlying galaxy overdensity field after 3.5 h^{-1} Mpc Gaussian smoothing. The length of the arrows is proportional to the average speed at that location.



Top: sky projection plots in Galactic coordinates of the number counts of spectroscopic 2MASS galaxies in the range 0-80 h^{-1} Mpc. *Bottom:* corresponding logarithm of number counts of particles from the reconstructed density field (one sample belonging to the highly correlated subsample).

Summary

We have developed KIGEN: a new self-consistent Bayesian approach to recover the initial fluctuations, cosmic web and velocity field corresponding to a distribution of galaxies in redshift space. We have applied this method to the 2MRS survey finding a velocity direction for the Local Group which is consistent with observations from the CMB-dipole. The results of this work are being used to make morphological environmental studies and to perform constrained simulations of the Local Universe. KIGEN is also being used to study the Sloan Great Wall and to perform reconstructions of the baryon acoustic oscillations.

References

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