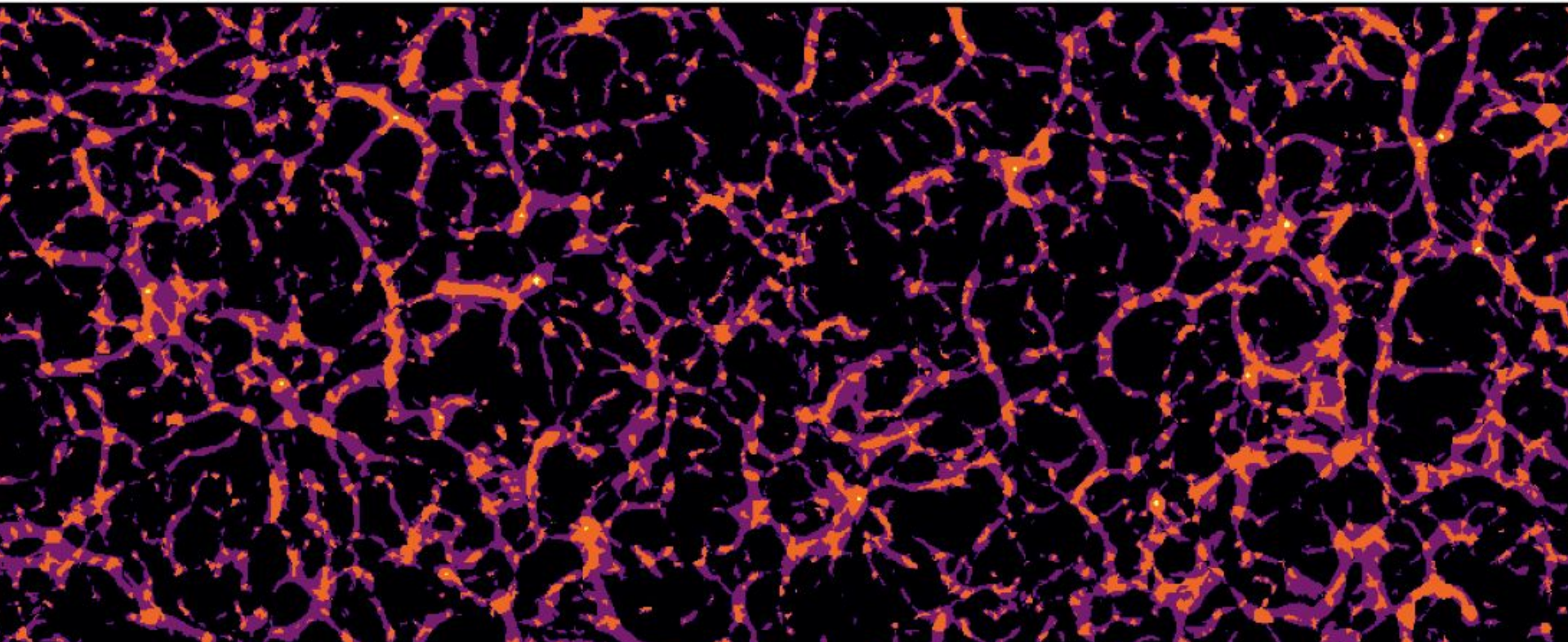
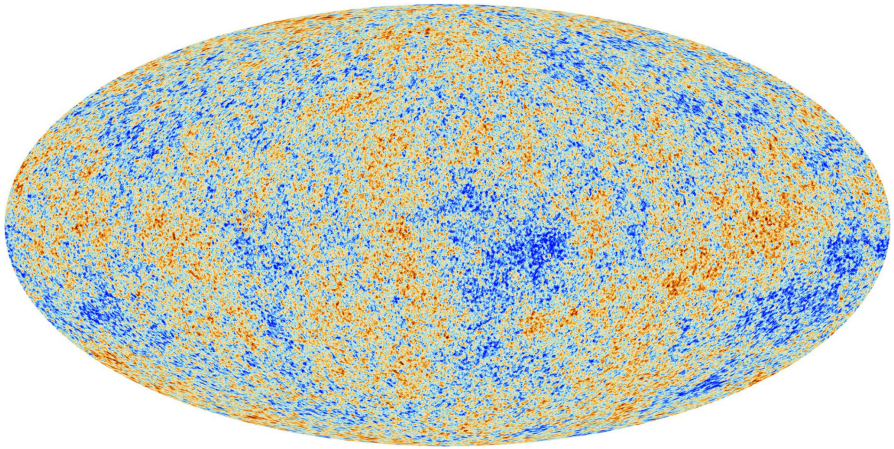
Probing neutrino mass using the Cosmic Web

Leonor Simões



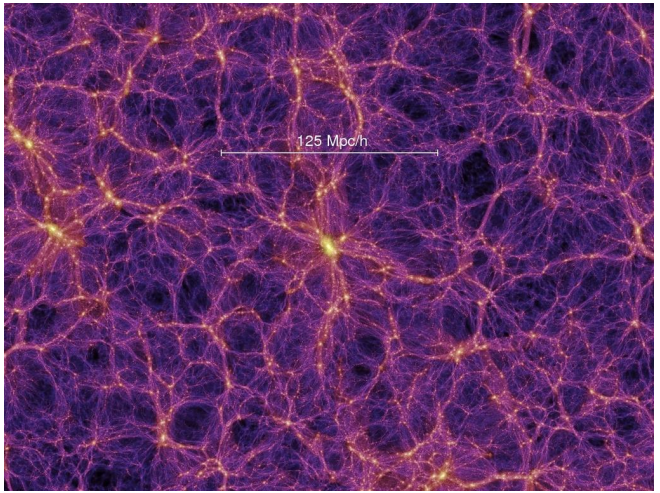
Big Picture

Early Universe



Approximately Gaussian.

Late Universe



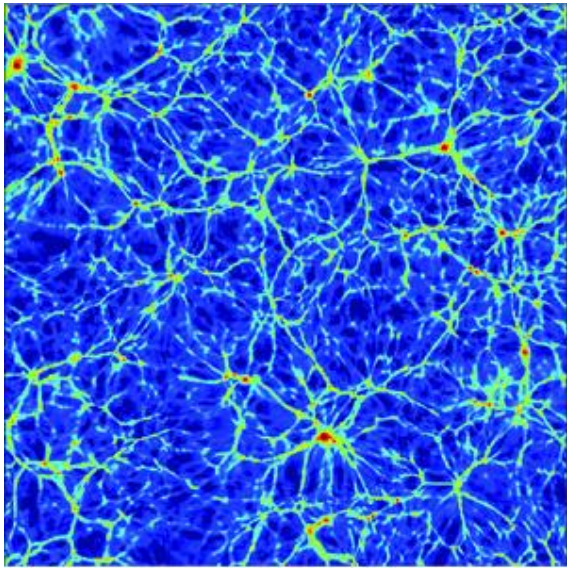
Highly non-Gaussian structure with complex dynamics.

Neutrinos in Cosmic Web simulations

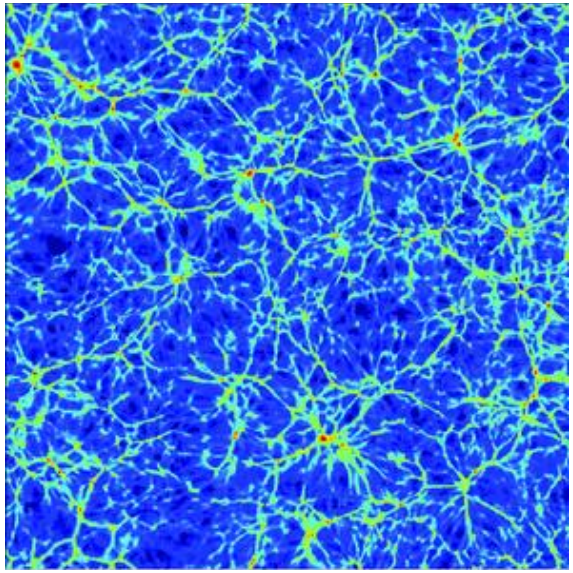
Particle physics ⟵ **0.060 eV ≲ Mν ≲ 0.077 eV** ⟶ Cosmology

DESI (2025)

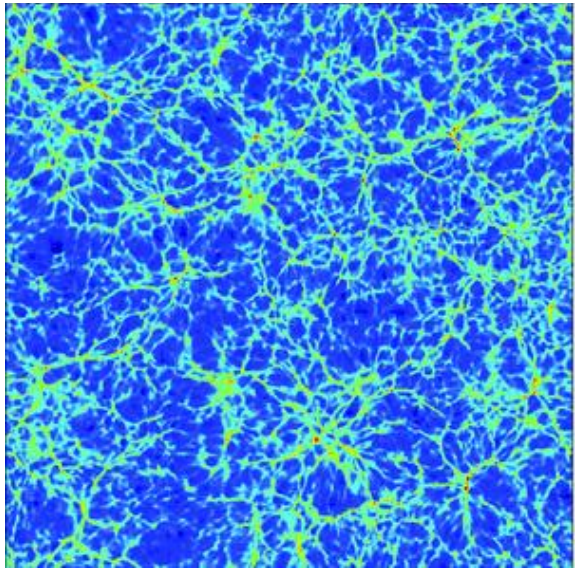
Agarwal & Feldman (2011)



No neutrinos

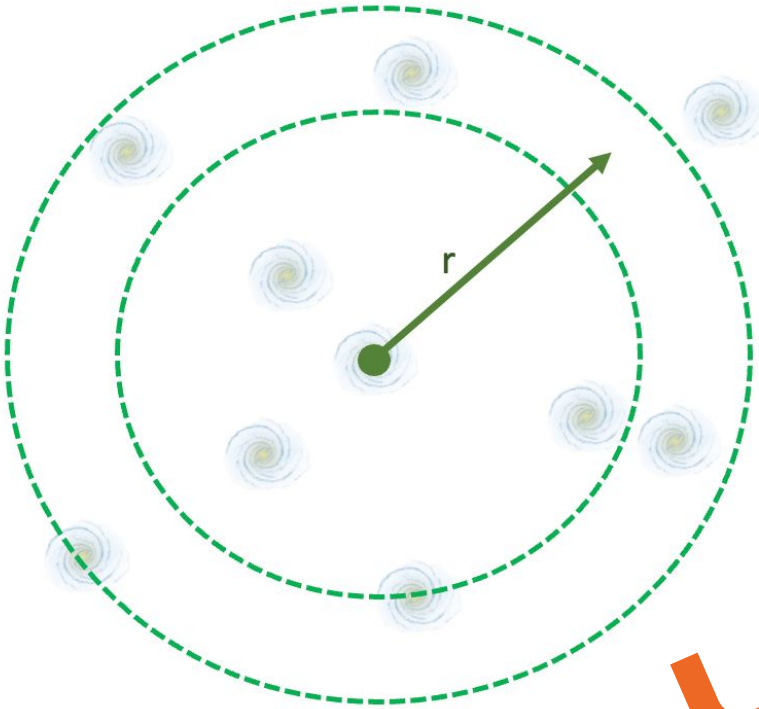


Mν = 0.95 eV

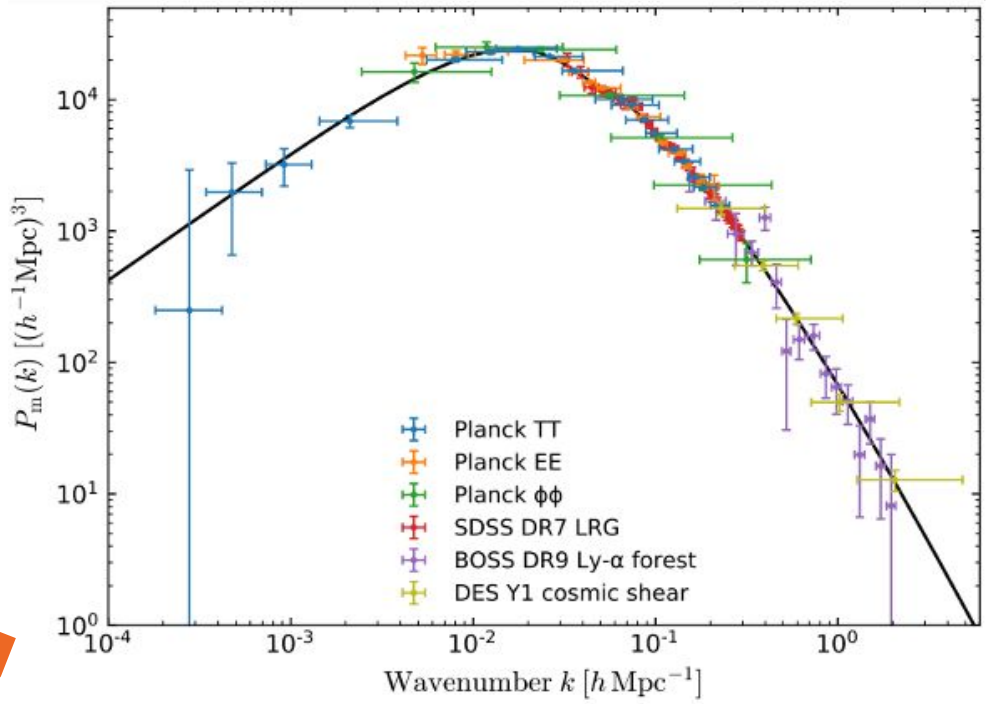


Mν = 1.9 eV

Two-point statistics

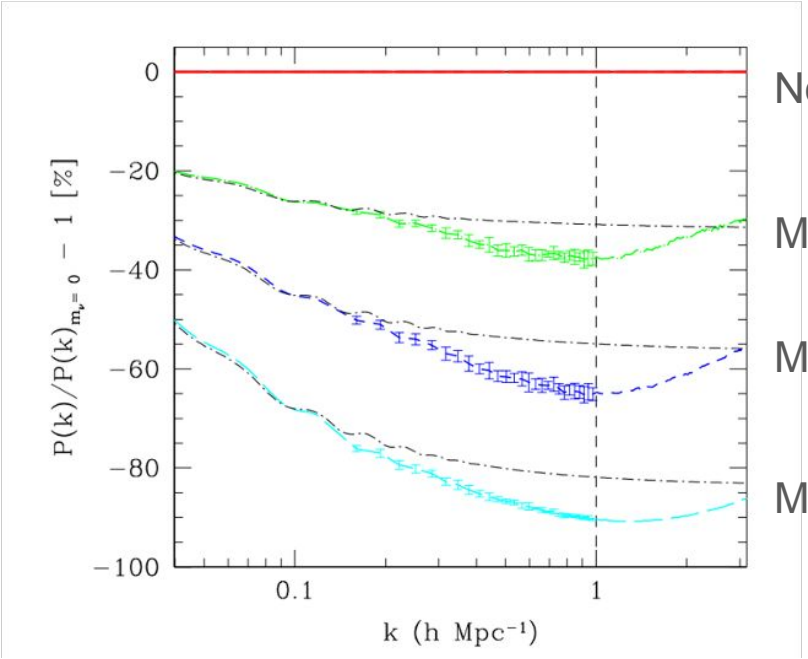


Fourier Space



ESA and the Planck Collaboration (2018)

Neutrinos and Baryons in Power Spectrum



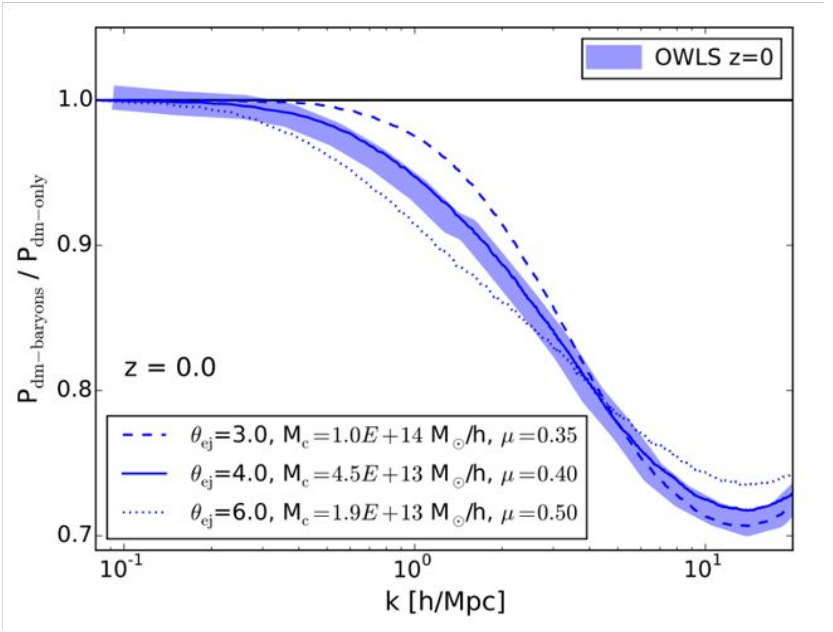
No neutrinos

Mν = 0.475 eV

Mν = 0.95 eV

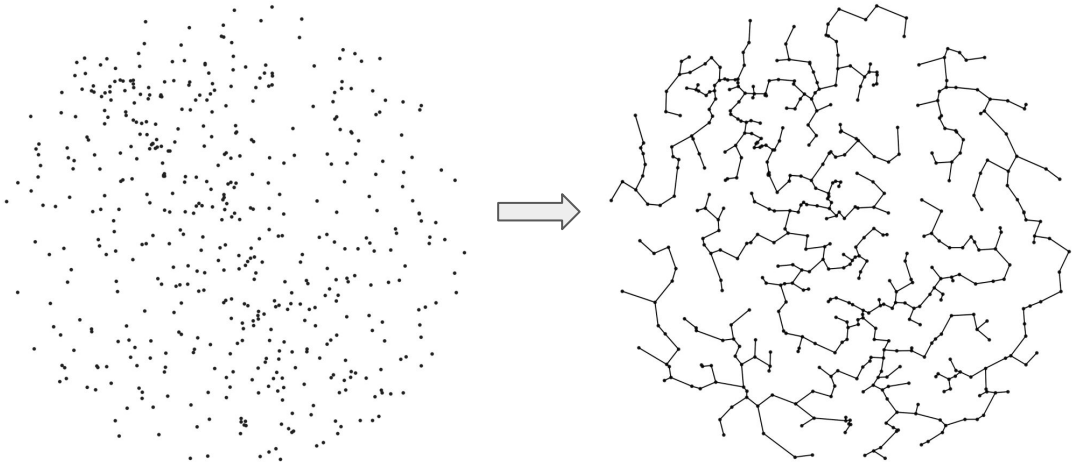
Mν = 1.9 eV

Agarwal & Feldman (2011)

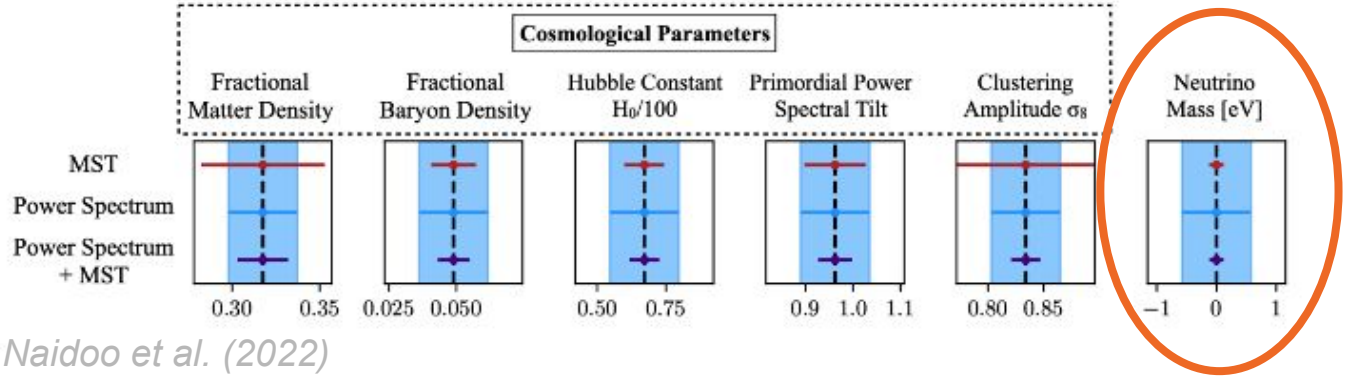


Schneider et al. (2019)

Beyond two-point statistics: Minimum Spanning Tree



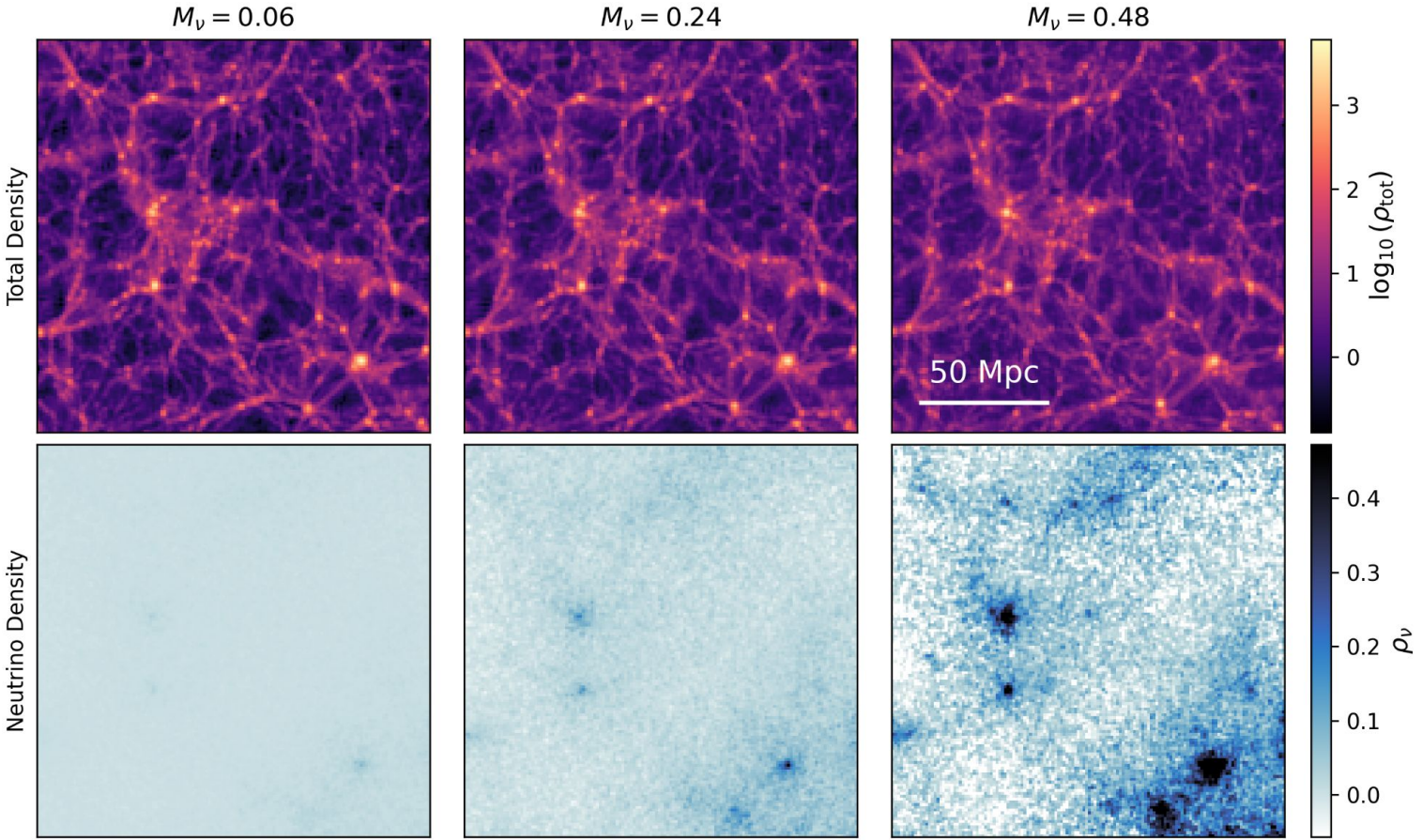
- **Minimum** — Minimise total length.
- **Spanning** — Connecting all nodes in a singular structure
- **Tree** — No loops



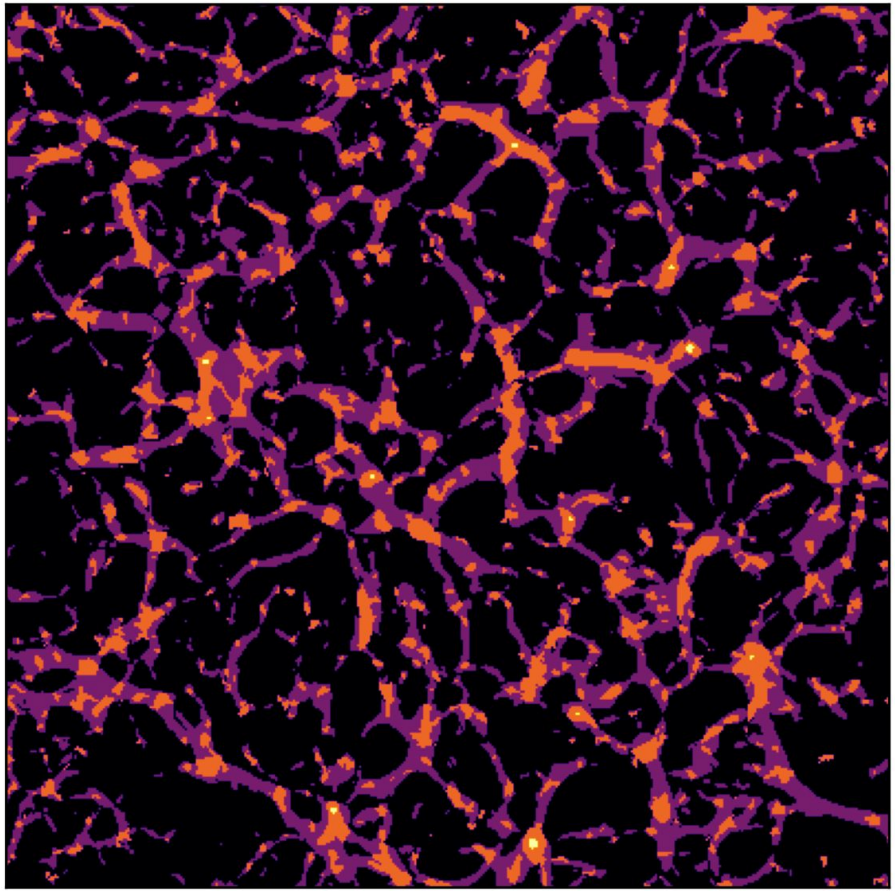
Where is the MST's sensitivity to neutrino mass coming from?

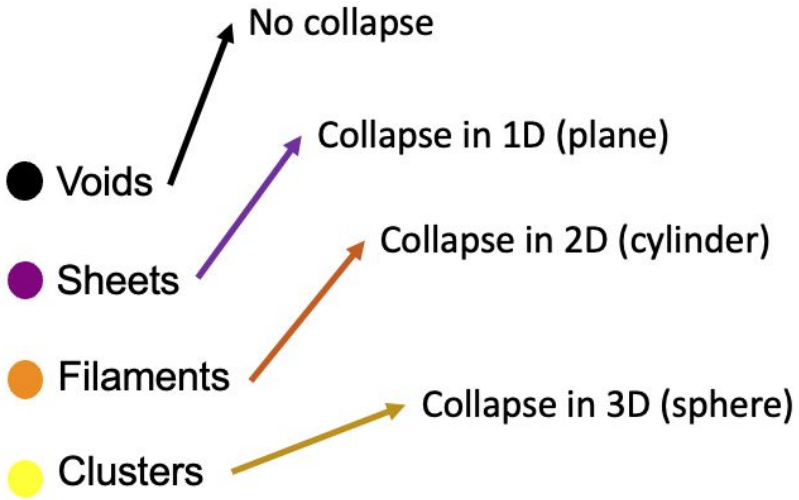
Naidoo et al. (2022)

The FLAMINGO simulations

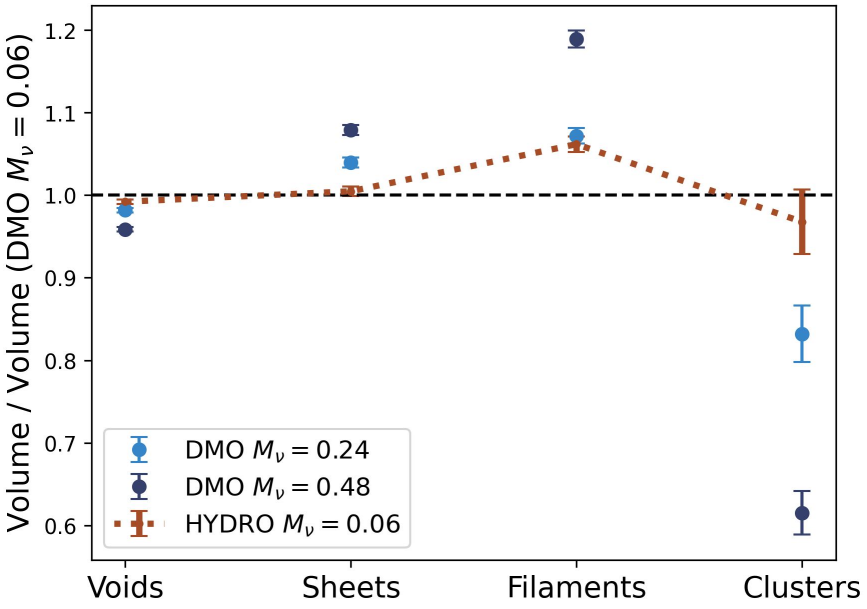


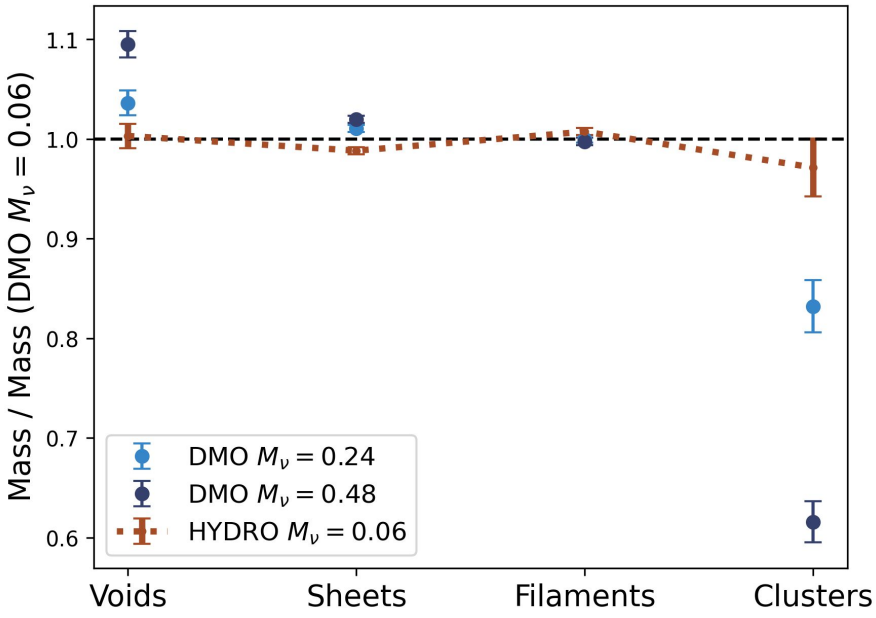
Cosmic Web classification with NEXUS+



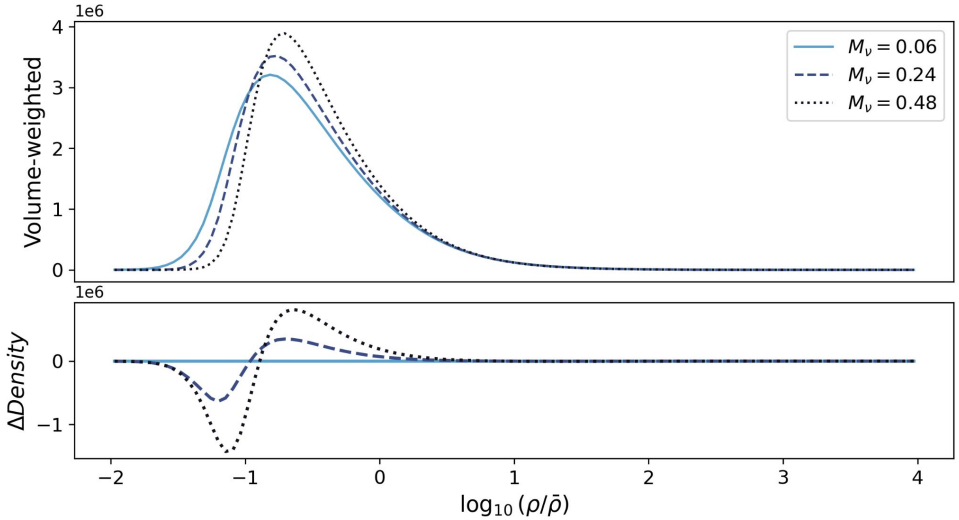


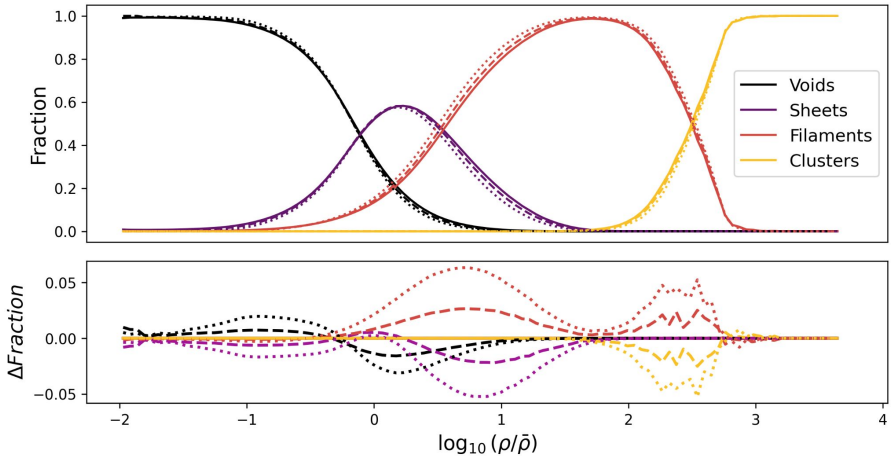
Volume and Mass fractions per component





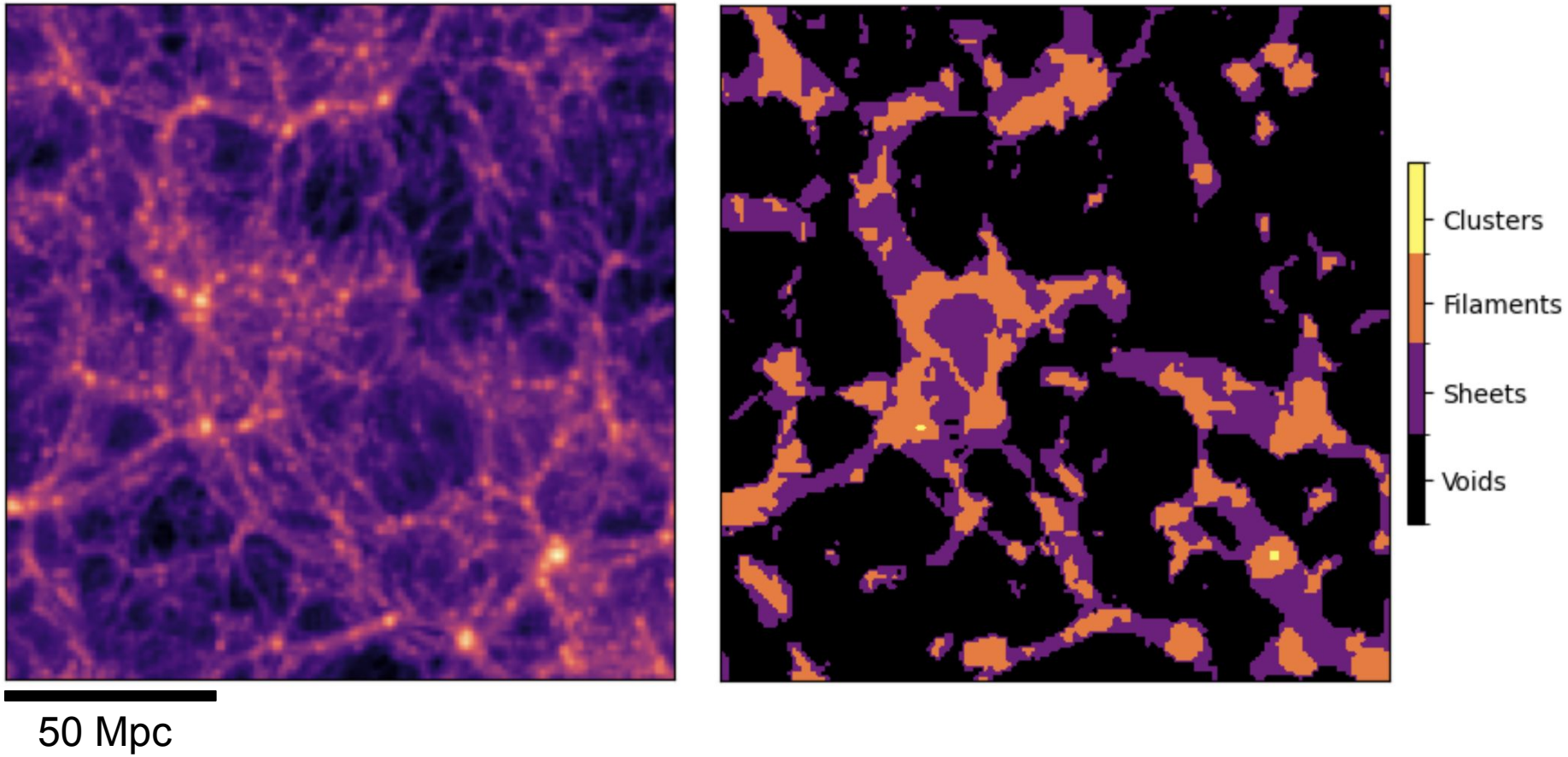
Density distributions





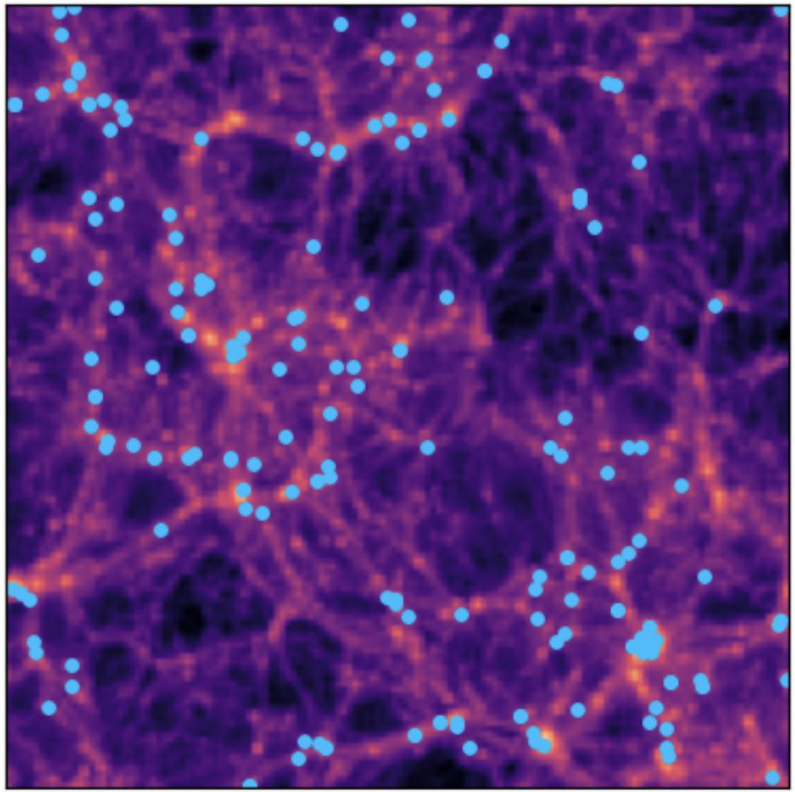
Increasing neutrino mass leads to a narrower density distribution.

Constructing the MST



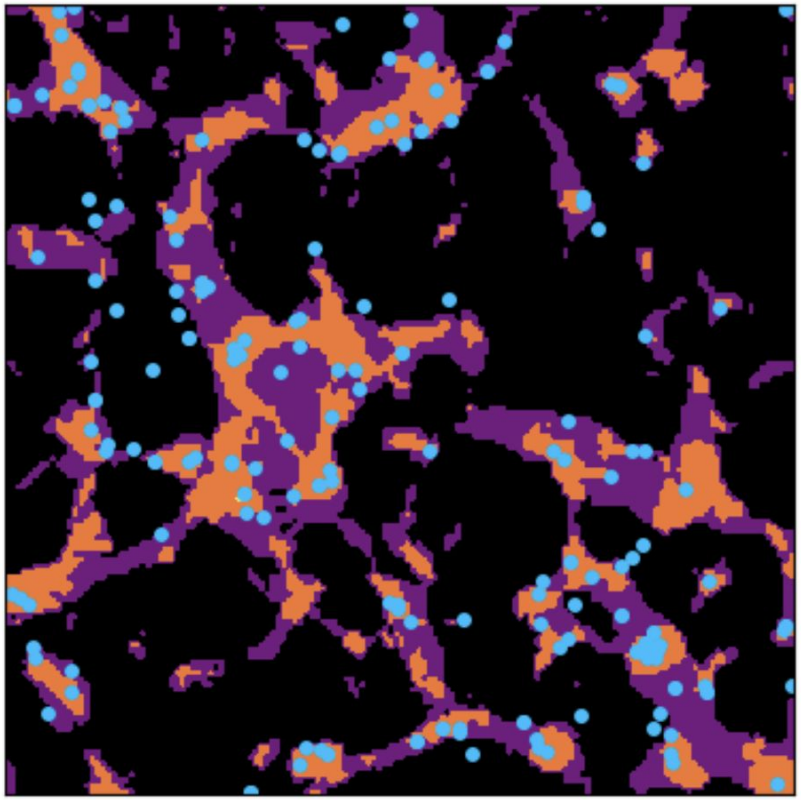
Constructing the MST

mass cut of $10^{12} M_{\odot}$



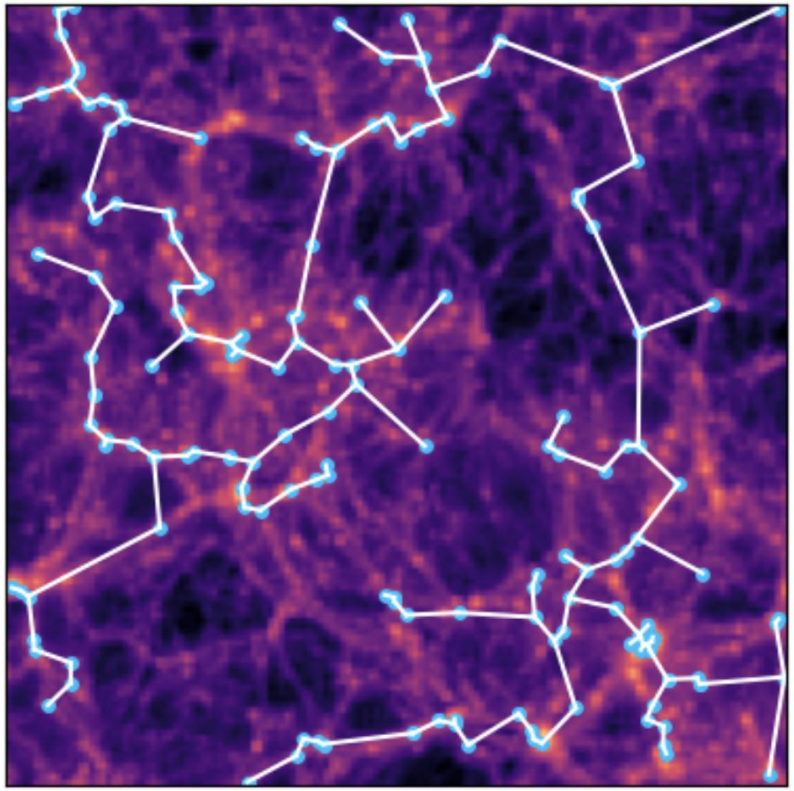
50 Mpc

pick 500 000 subhaloes at random



Constructing the MST

mass cut of $10^{12} M_{\odot}$



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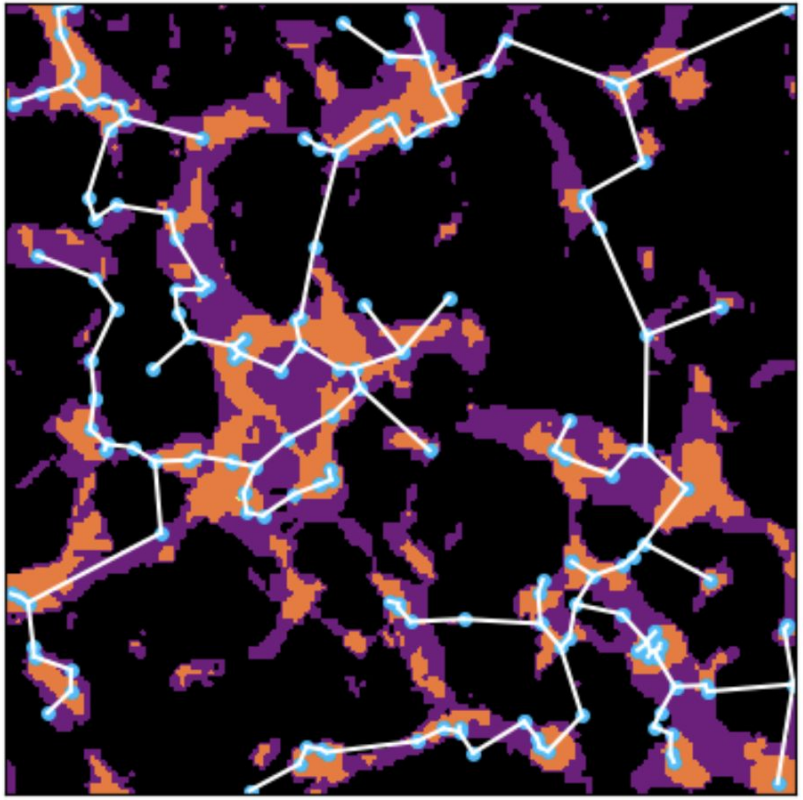
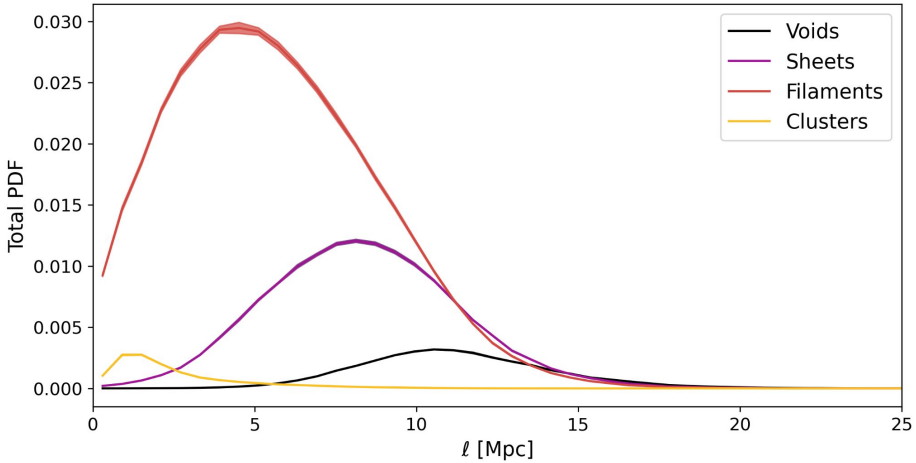
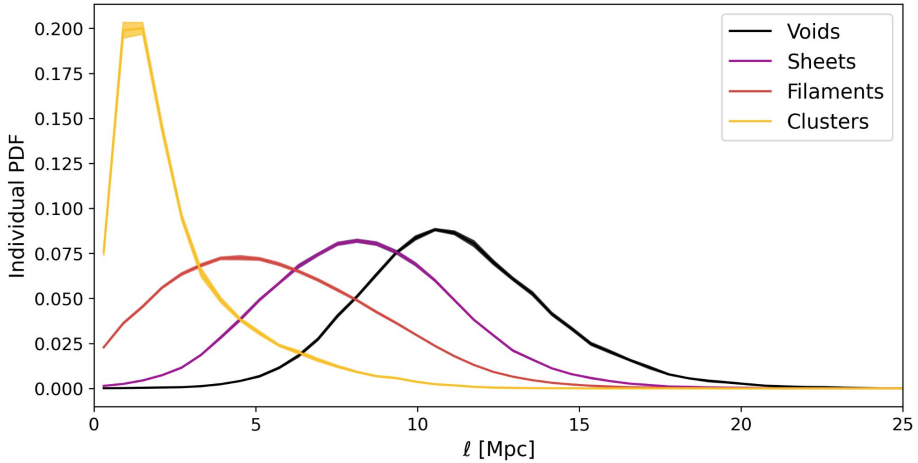


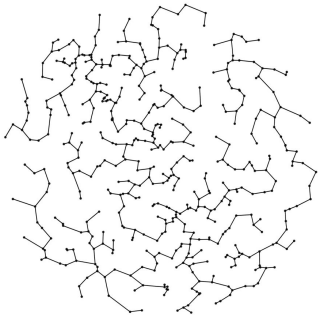
MiSTree

How does the MST trace the Cosmic Web



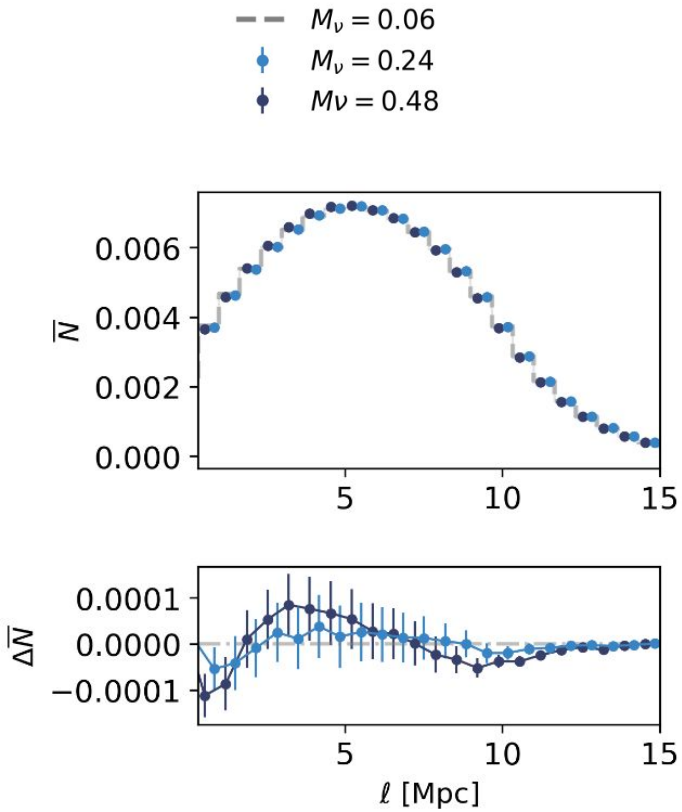


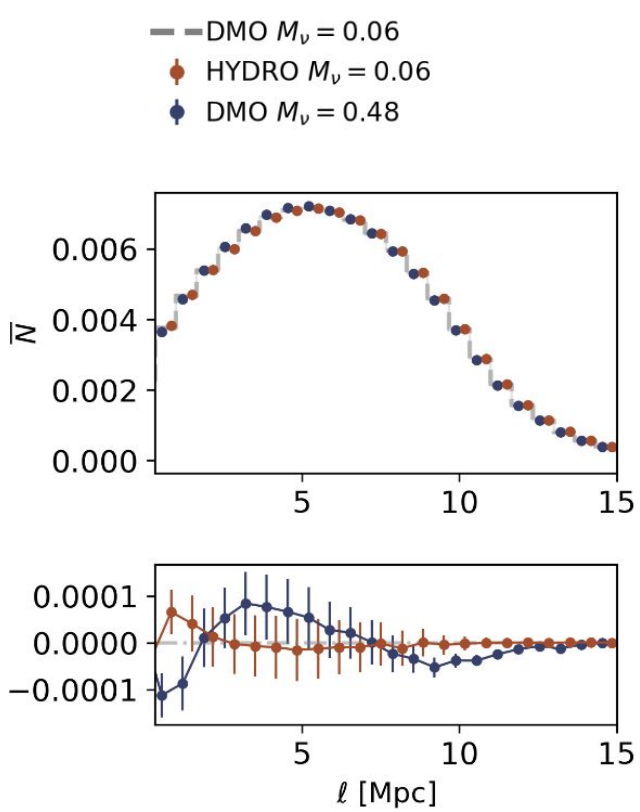
MST picks out filaments

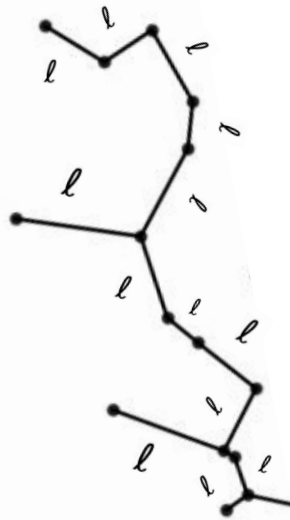


Hierarchy of classifications

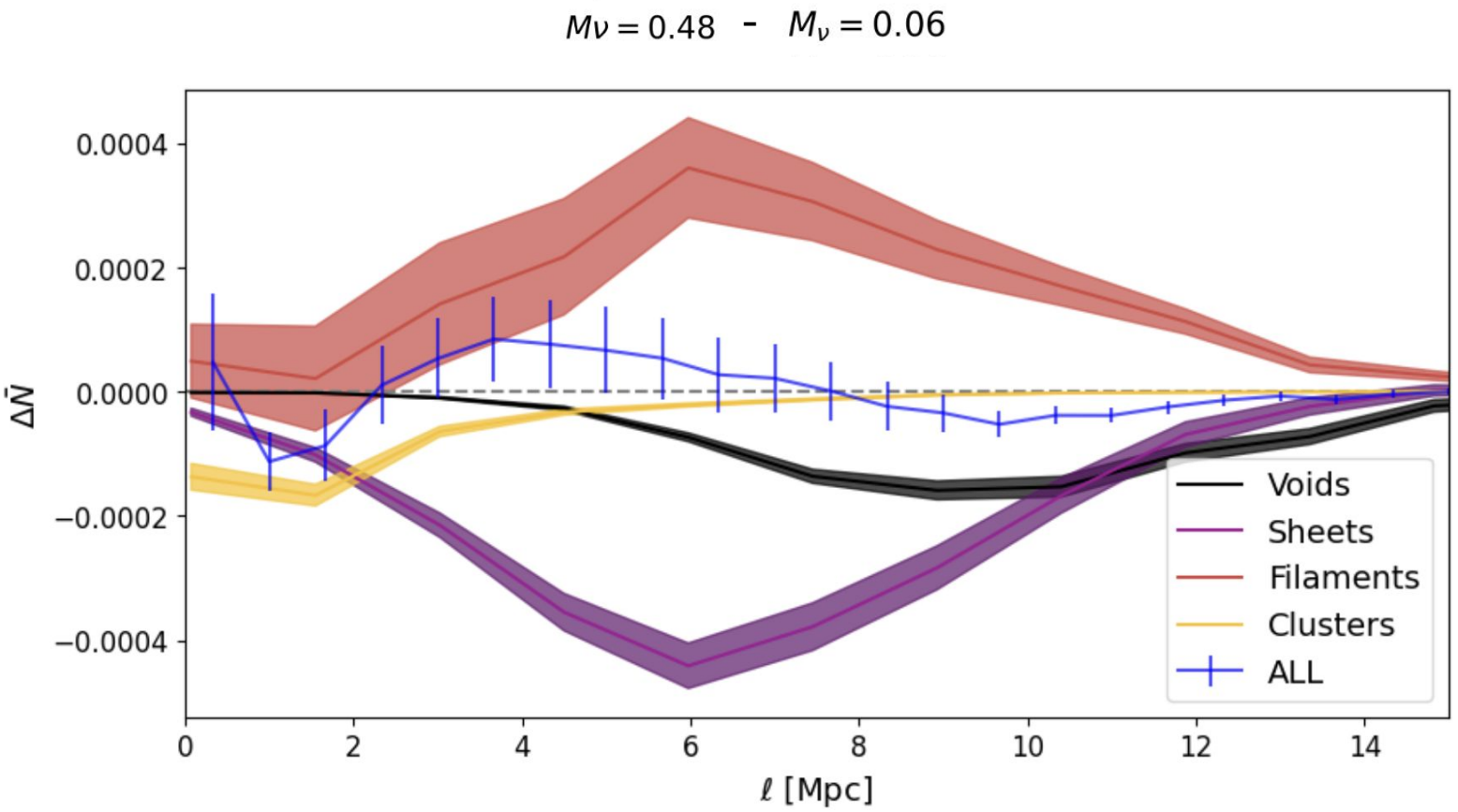
MST statistics







MST statistics by environment



Summary and future work

- Neutrinos delay structure formation, affecting the cosmic web structures.
- The MST edges probe different environments and are sensitive to neutrino effects.
- We hope to use MST statistics in upcoming large-scale structure surveys to improve constraints on cosmological parameters (Naidoo & Lahav 2025).


Thank you!