THE COSMIC GRAPH: HOW MUCH INFORMATION IS IN LARGE-SCALE STRUCTURE, AND WHERE IS IT HIDING?

ML x Cosmo @IAP

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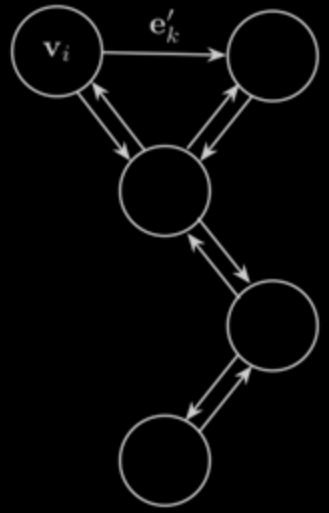
Cosmic Graphs

Makinen et al (2022) arXiv:2207.05202

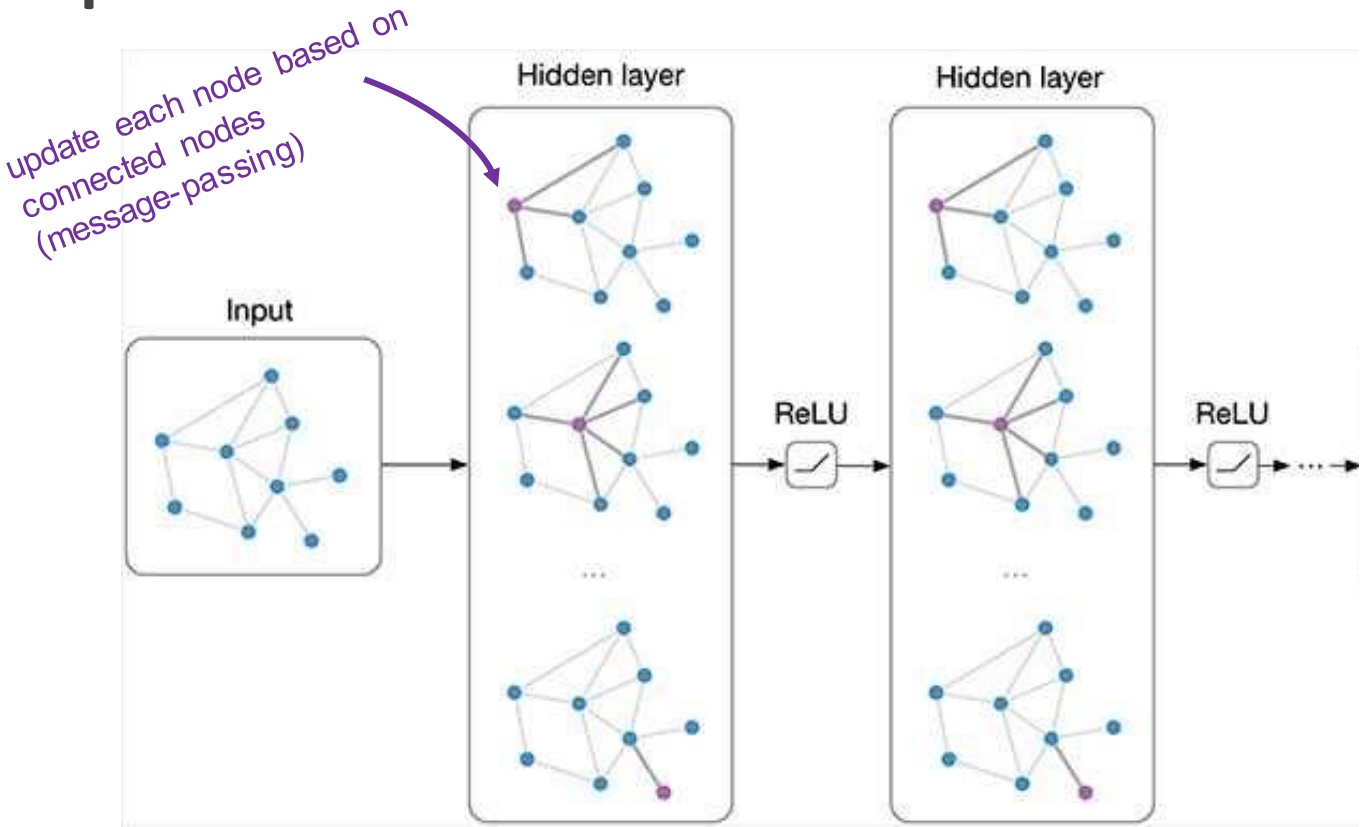
Graphs 101



$$G = (V, E, u)$$

- A graph G is a *tuple* of nodes $V = \{v_i\}$, edges, $E = \{e_k, s_k, r_k\}$, and global features u
- Each node and edge is a *vector*
- Edges propagate information to nodes, via senders $\boldsymbol{s_k}$ and receivers $\boldsymbol{r_k}$

Graph Neural Networks



global summaries x

Makinen et al (2022) arXiv:2207.05202

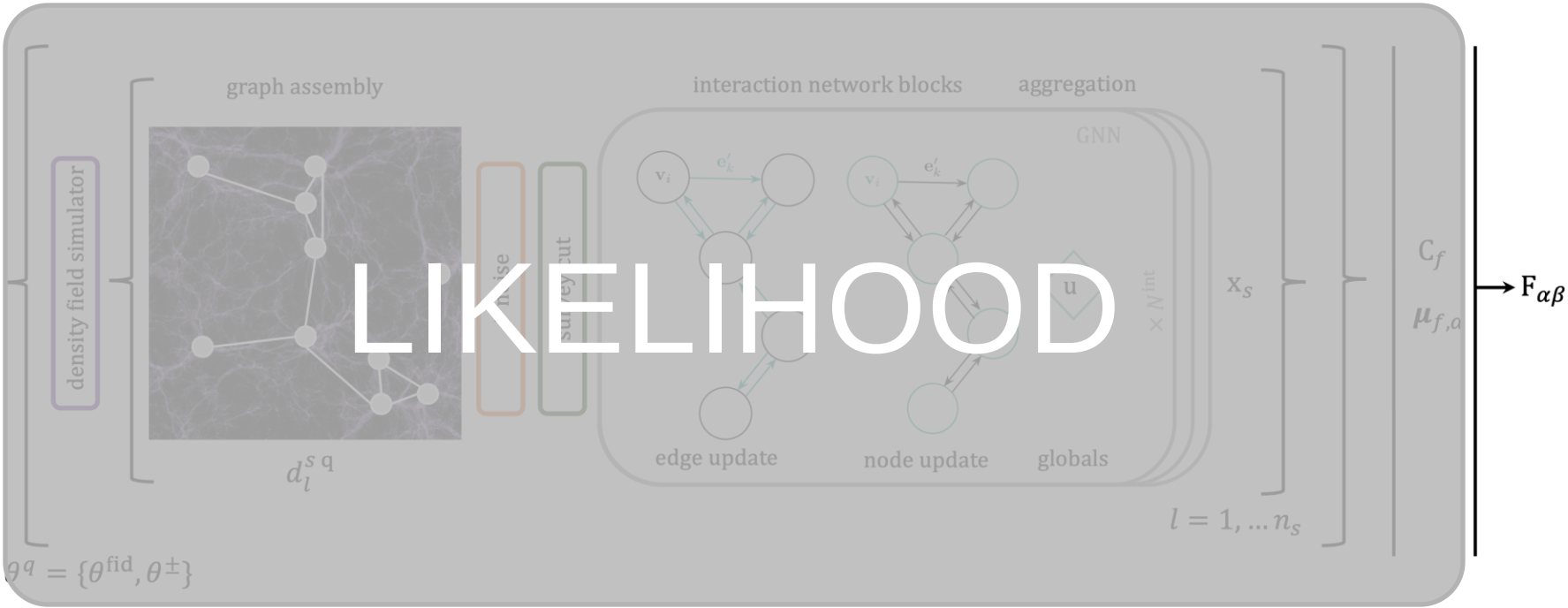
Halo graph representation

Nodes: masses (positions)

Edges: distances and angles between halos

how sensitive is the graph structure to cosmology ?

Halos assembled from *Quijote* simulation suite

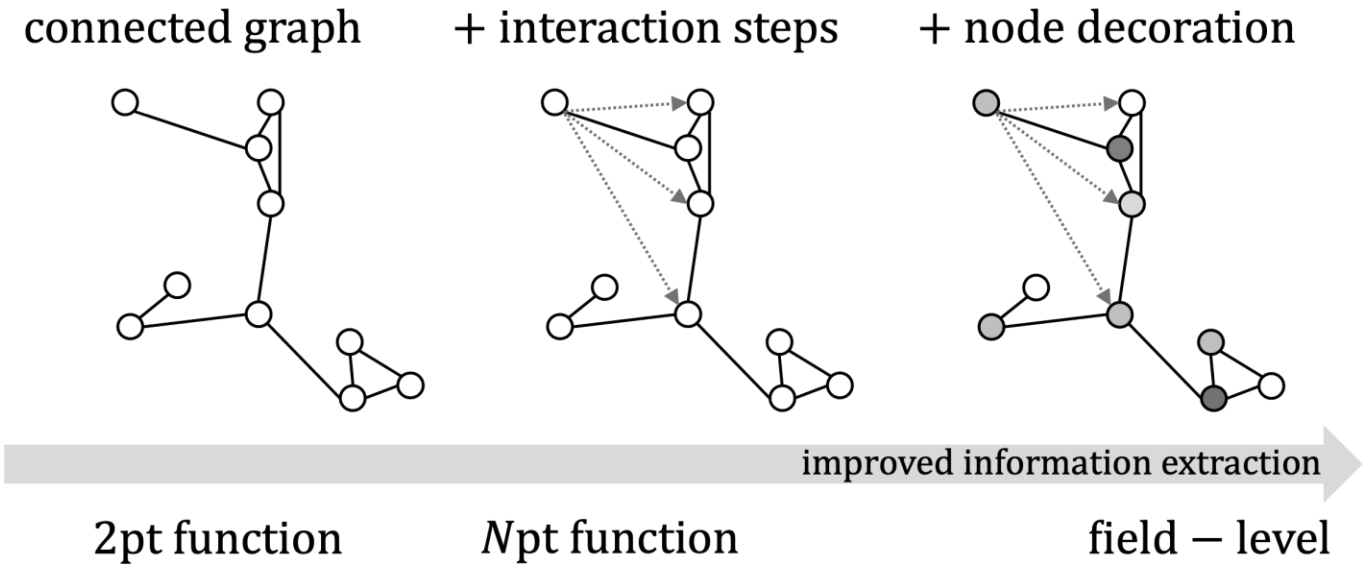


LIKELIHOOD

Makinen et al (2022) https://arxiv.org/abs/2207.05202

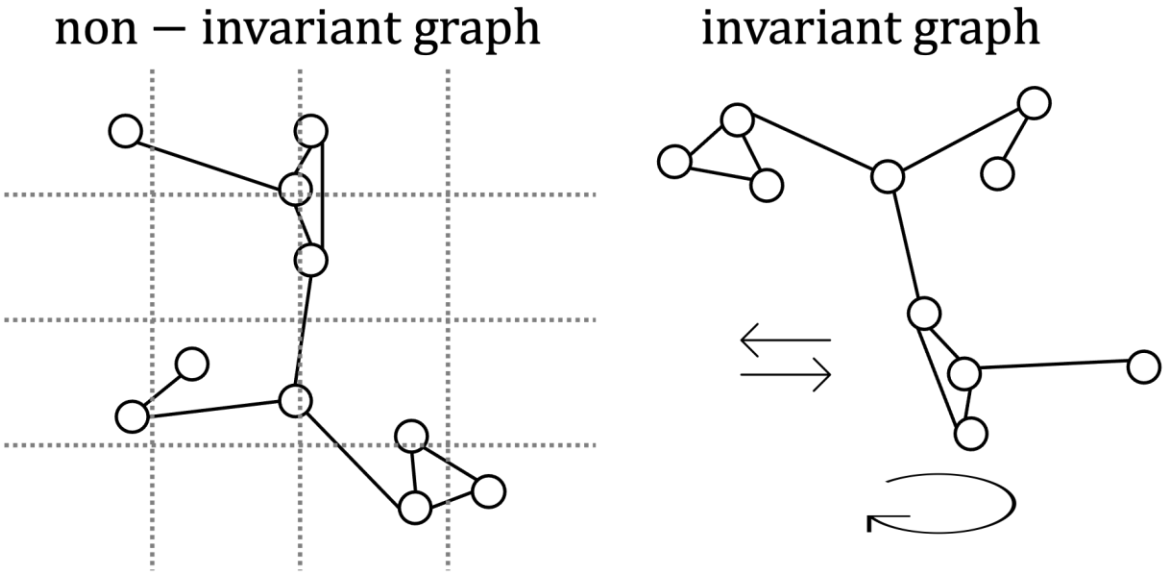
Graphs: super modular

Where is the information hiding ?



Makinen et al (2022) arXiv:2207.05202

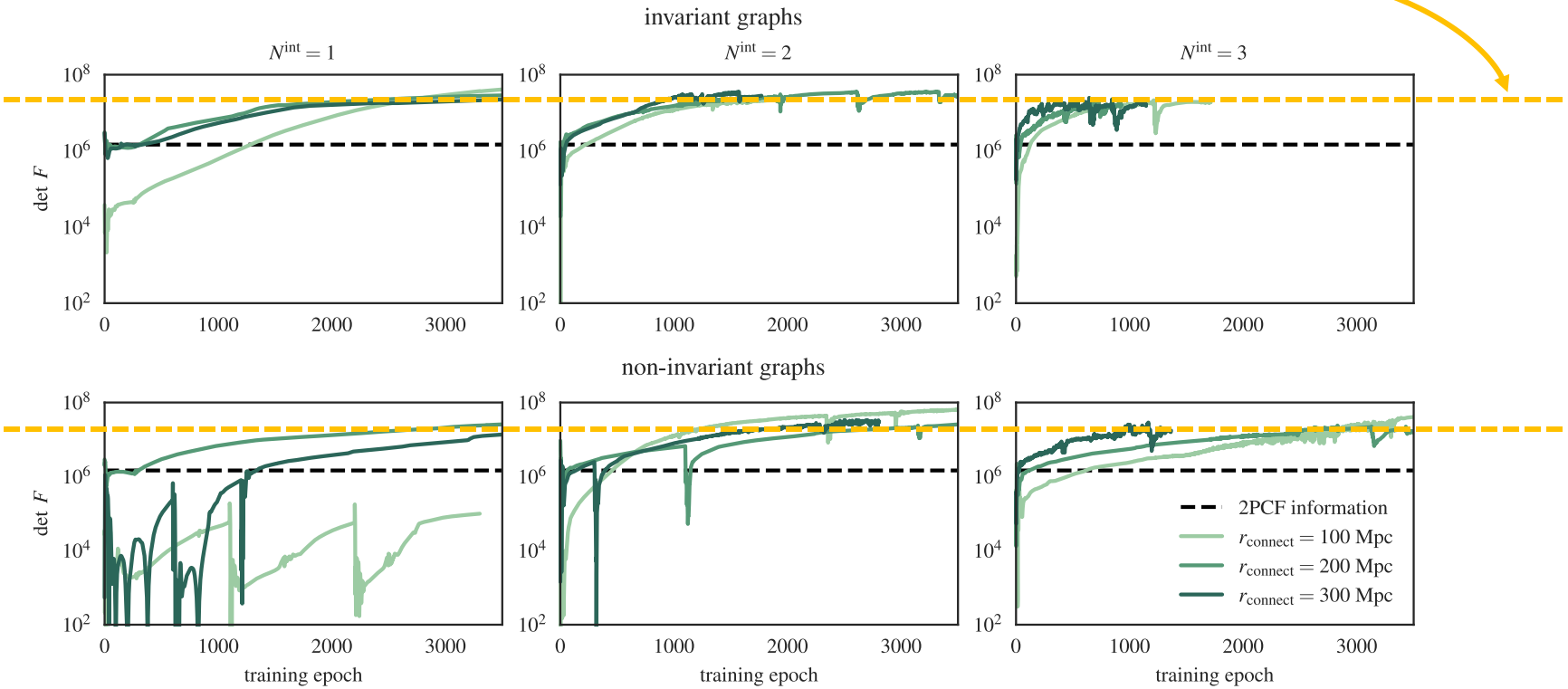
Invariant vs non-invariant graphs



Makinen et al (2022) arXiv:2207.05202

Graphs: super modular

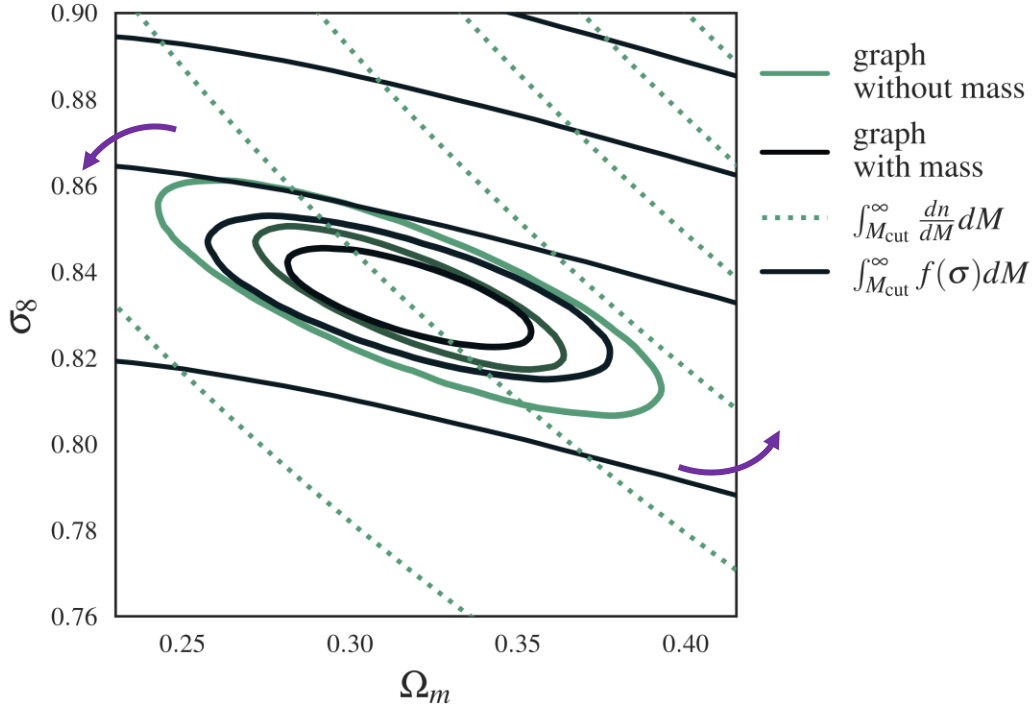
Information plateaus to the same level acros
graphs / network architectures



Makinen et al (2022) arXiv:2207.05202

What's being learned ?

adding mass pushes us towards the HALO MASS FUNCTION



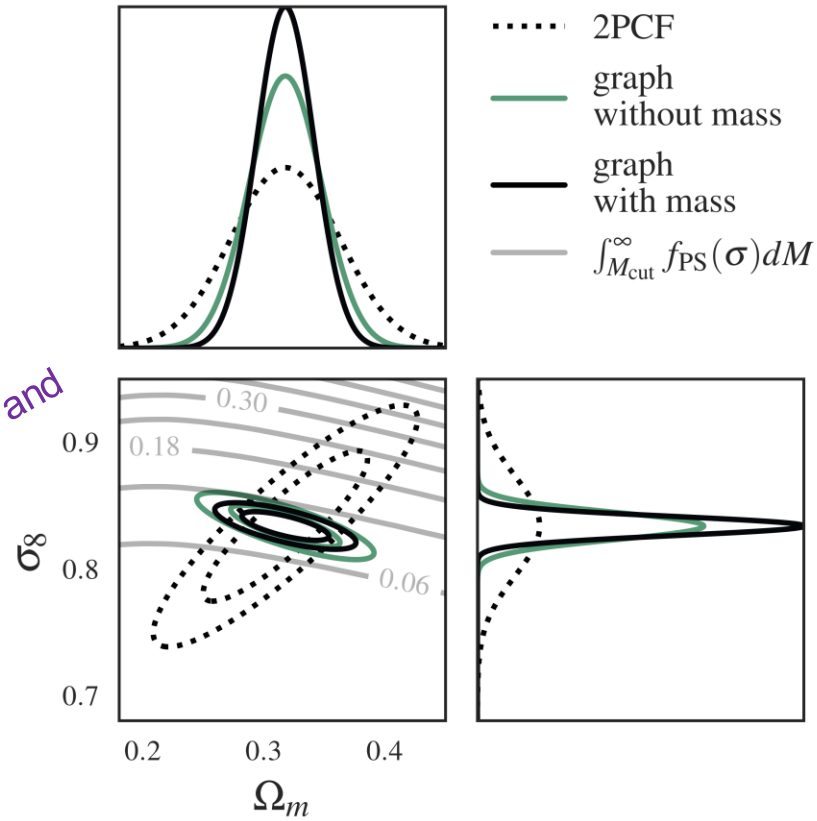
What's being learned ?

fixing catalogue length removes cardinality feature – network can no longer learn number or mass density !

catalogue N^v	graph assembly	$\ln \det F$	epistemic	**aleatoric**
fixed	without mass		5.03 ± 0.47	$\mathbf{5.98 \pm 1.06}$
	with mass		12.43 ± 1.44	$\mathbf{12.39 \pm 0.22}$
	2PCF	9.74		
variable	without mass		17.89 ± 0.33	$\mathbf{17.66 \pm 0.27}$
	with mass		17.40 ± 0.57	$\mathbf{17.85 \pm 0.12}$
	2PCF	14.19		

Graphs: super modular

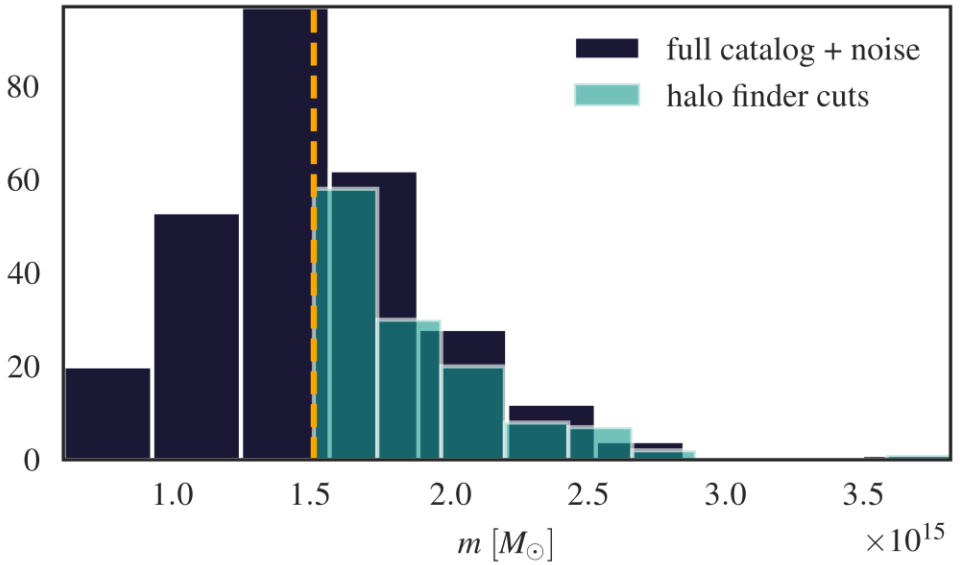
Where is the information hiding ?



Network automatically combines clustering and mass information !

Adding Noise

Forward-simulate noise and catalogue cuts !



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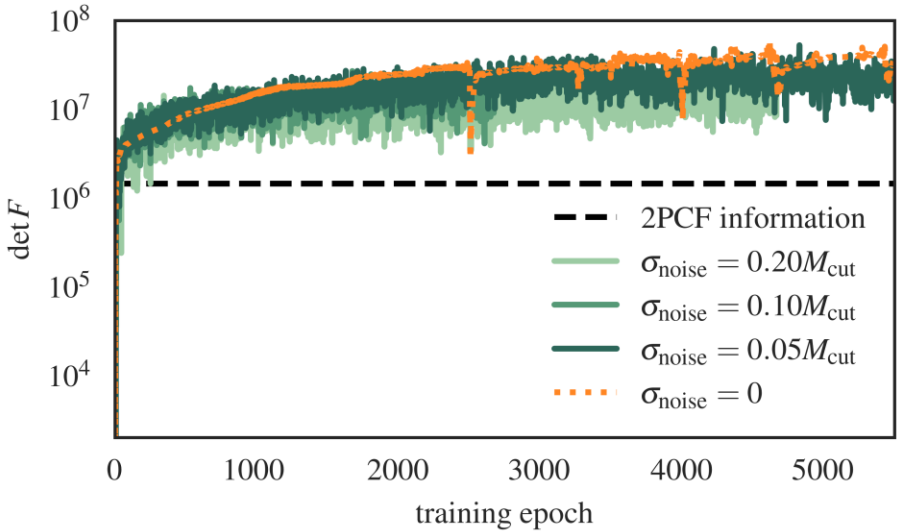

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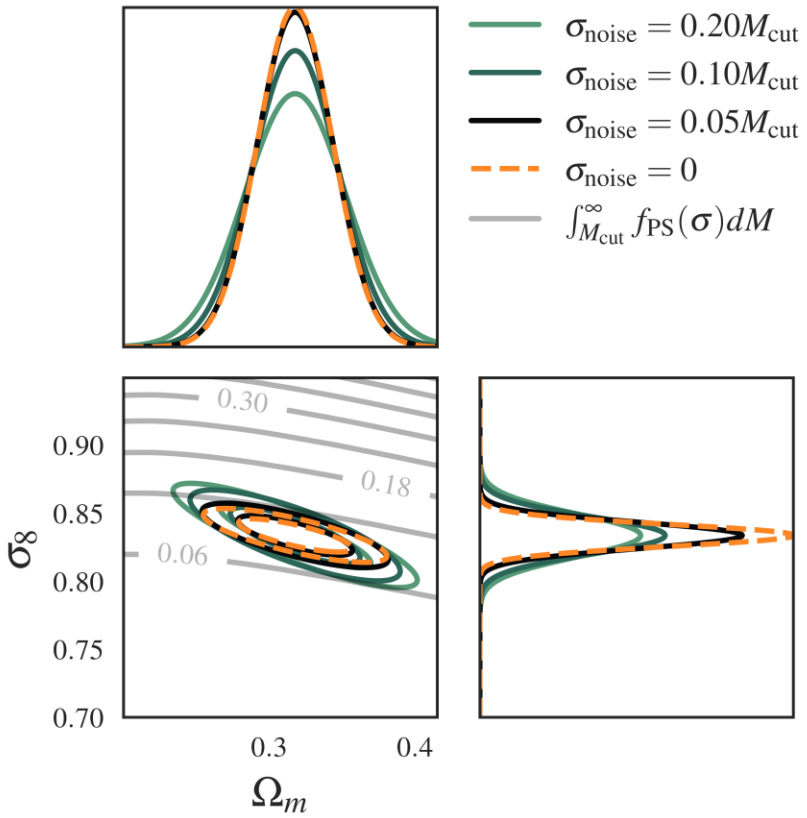

THANKS !


https://tlmakinen.github.io/


https://github.com/tlmakinen


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