Constraining Ωm with phase-space information of galaxies

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Galaxy Formation and Evolution in the Data Science Era
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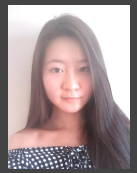
Is there an optimal way to do parameter inference?

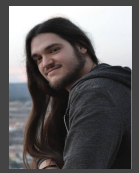
arXiv: 2302.14101


Helen


Paco


Raul


Romain


Pablo


Yueying

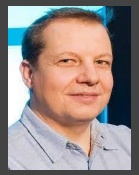

Daniel


Shy


Elena


Ulli

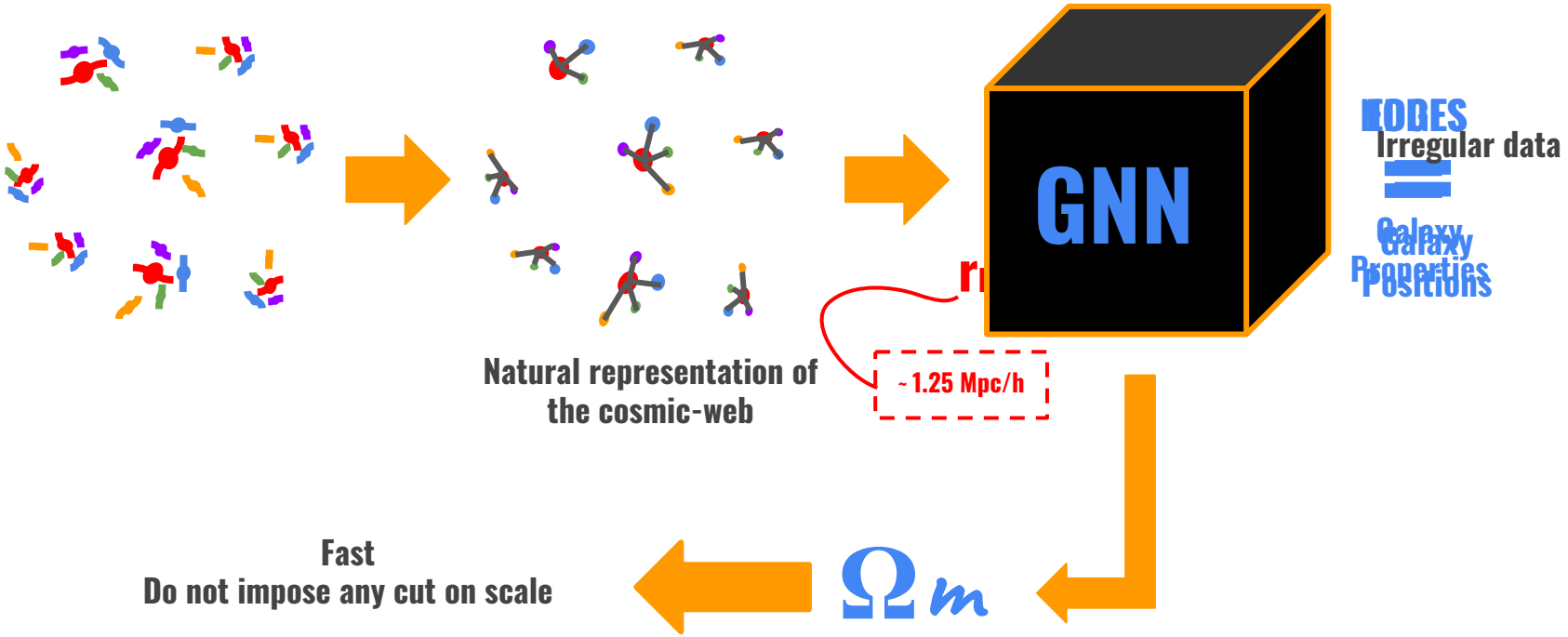

Chris


Klaus

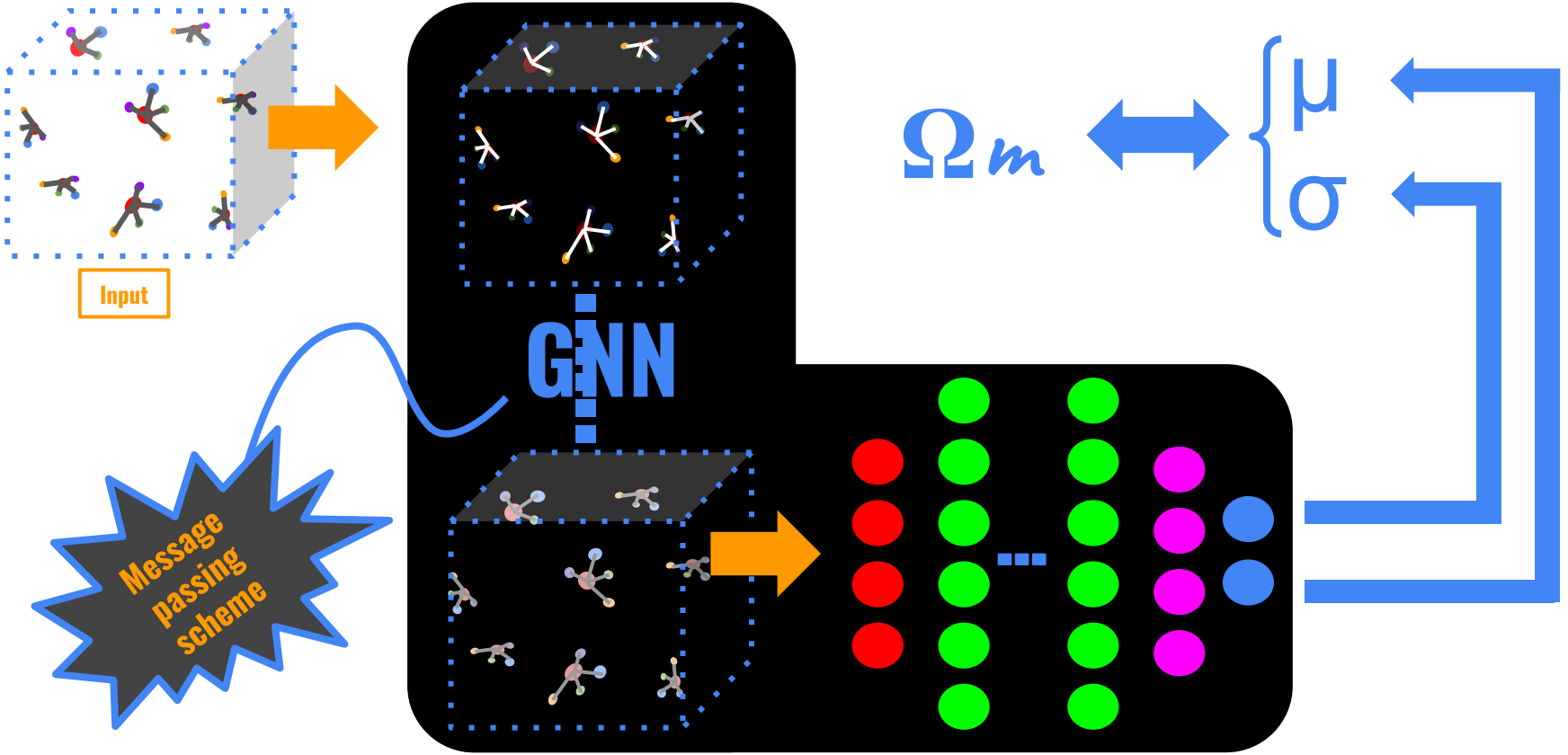

Tiago


Mark

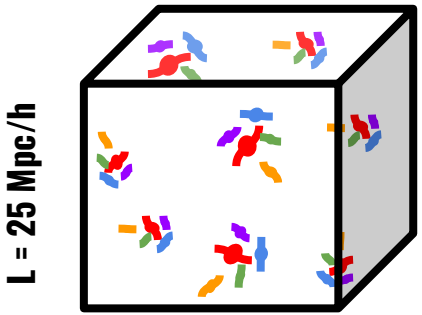
Galaxy field-level likelihood-free inference



Graph Neural Networks - GNNs

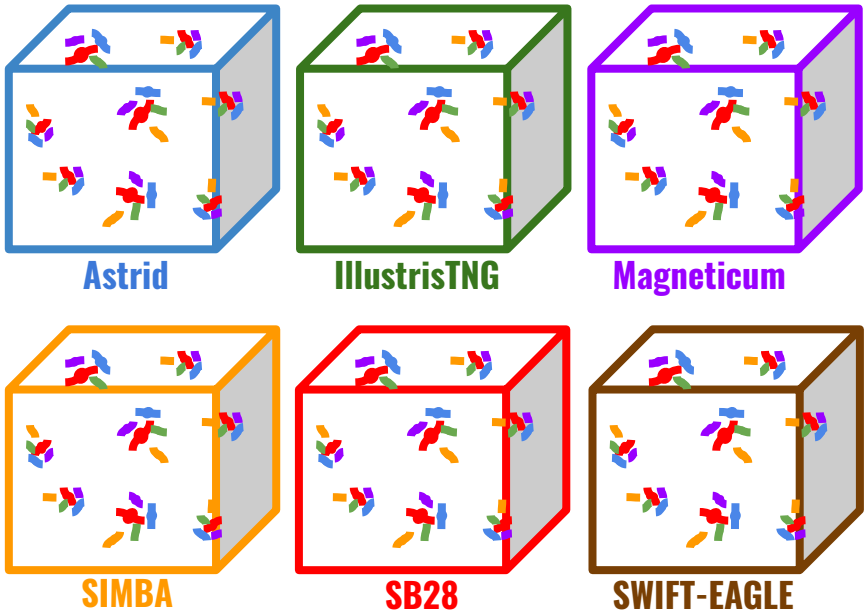


CAMELS



- **Parameters:**
  - **Cosmological:** Ω_m, σ_8
  - **Astrophysical:** A_{SN1}, A_{SN2}, A_{AGN1}, A_{AGN2}

- **Different models:**

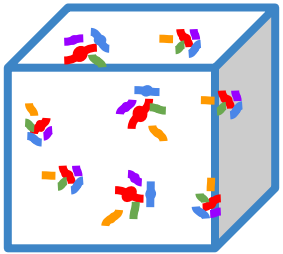


The best model

Galaxy Information

3D Positions
z component of the velocity

Train set



Astrid

Test set

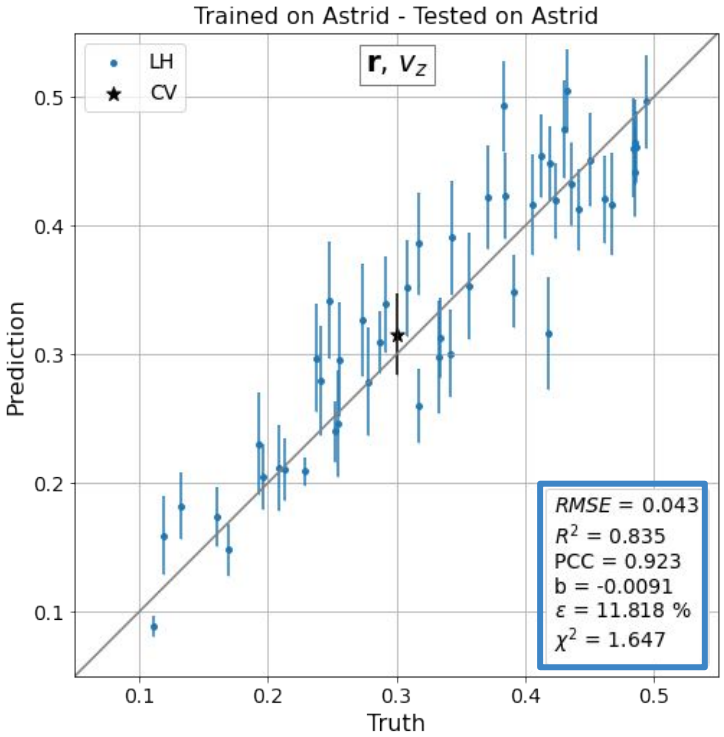
Astrid
SIMBA
IllustrisTNG
SB28
Magneticum
SWIFT-EAGLE

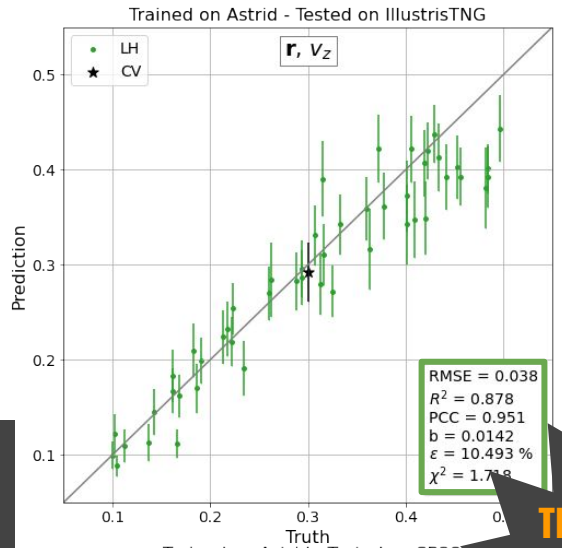
GNN

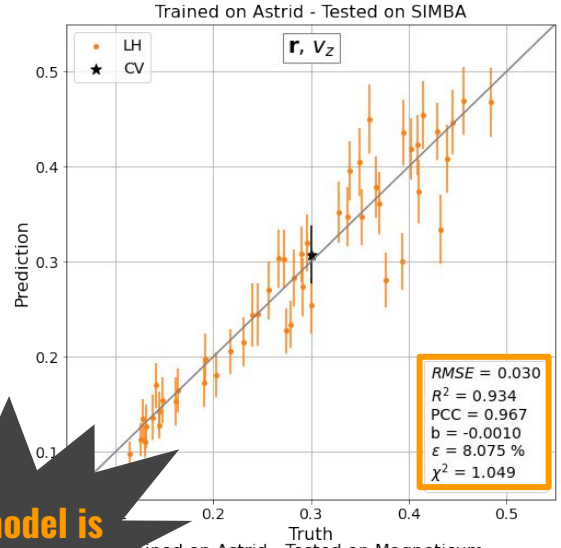
Ω_m

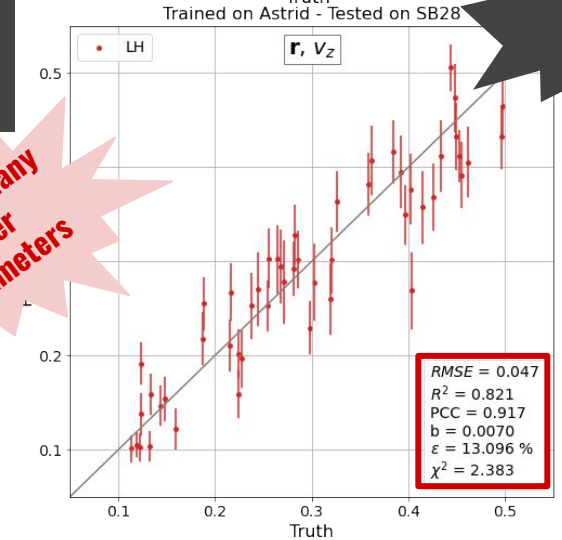
The best model

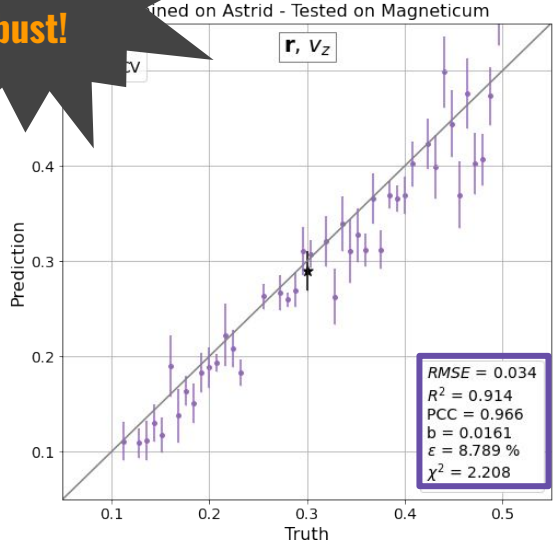
Sanity check

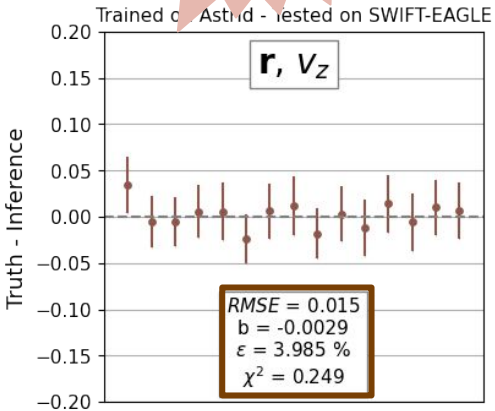












Robustness

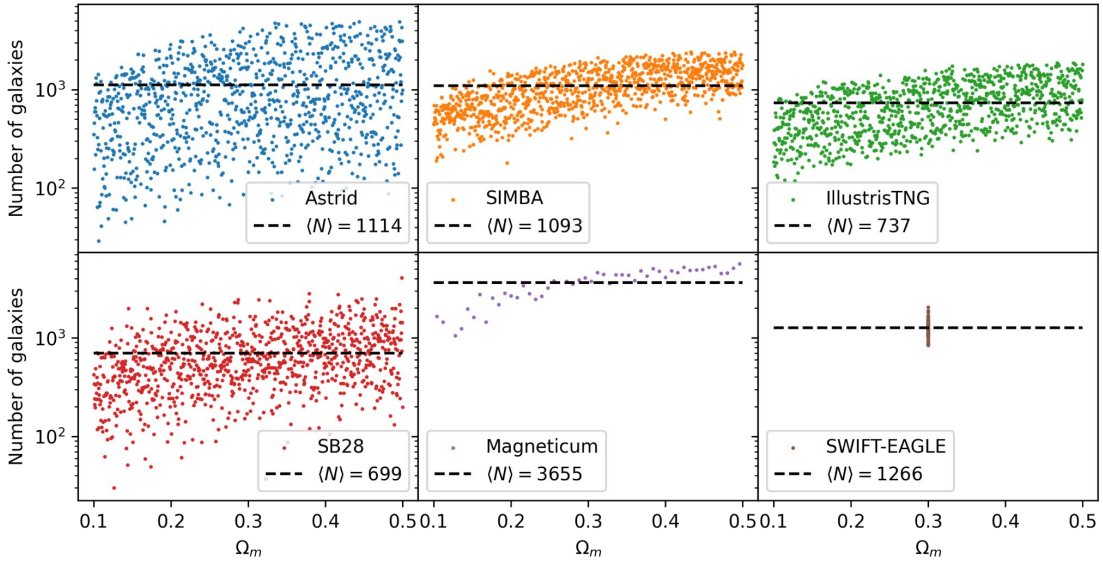
The model is robust!

Varying many other parameters

Using halos/subhalos found with a different finder

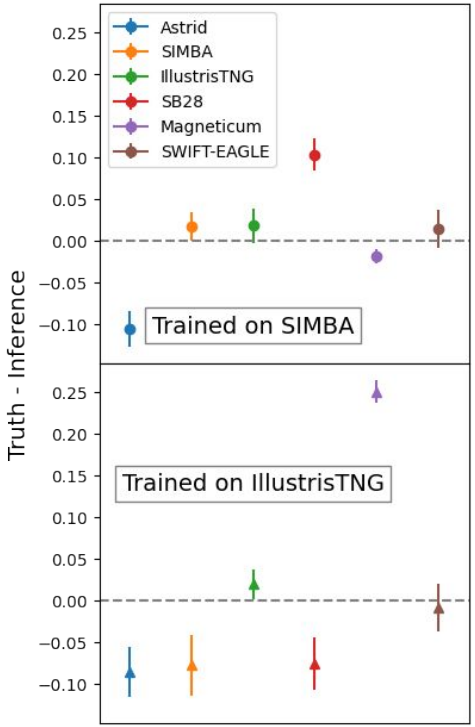
Why the model trained on Astrid is so good?

- We have a **broader variation** in the **number of galaxies** in **Astrid** catalogs

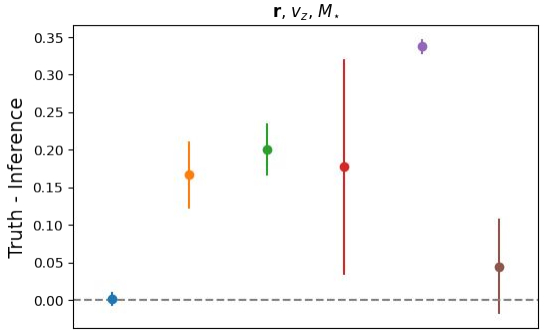


- **Astrid** produces **larger variation in some galaxy properties** given the parameter variations

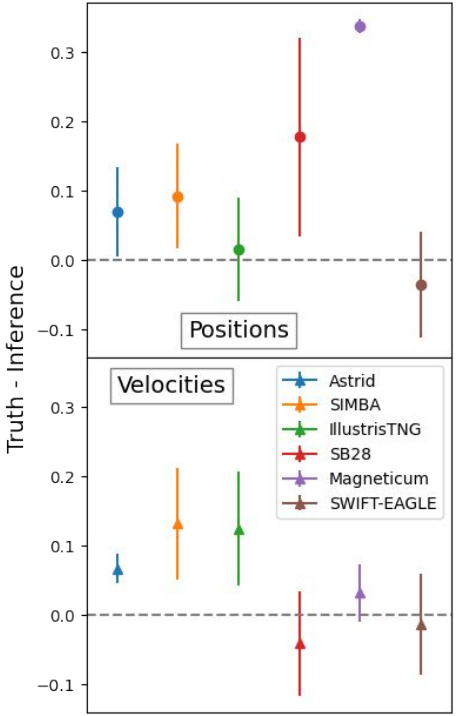
Training on SIMBA and IllustrisTNG



Including stellar mass

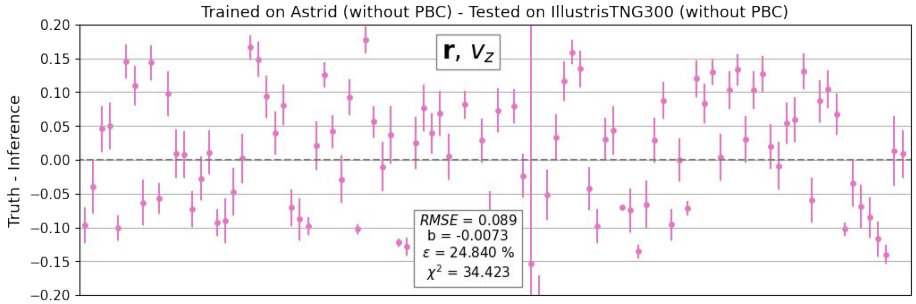


Only positions or velocities



Real data?

- The method need to be shown robust to changes in **super-sample covariance**
- Error in the measurements in the peculiar velocities
- Take care of **selection effects**



A physical interpretation?

A universal equation to predict Ωm from halo and galaxy catalogues

Shao+2023 arXiv: 2302.14591

- We can use **Symbolic Regression** from **GNNs** to constrain Ω_m
- Training on **halo** catalogs: **velocity modulus** and **positions**
- A step in the direction for a physical interpretation behind the success of the GNNs
- The model is **robust** and **works on galaxy catalogs too!**

Takeaway messages

The most important galaxy properties for the GNN constrain Ω_m:

galaxy positions and velocities (z component)

We can constrain Ω_m for:

5 different hydrodynamical simulations

	ε	χ^2
Astrid	11.8 %	1.6
SIMBA	8.1 %	1.0
IllustrisTNG	10.5 %	1.7
SB28	13.0 %	2.4
Magneticum	8.8 %	2.2
SWIFT-EAGLE	4.0 %	0.3

We are giving the first steps to applying this machinery to real data!

Thank you for your attention!