Contribution ID: **122** Type: **Poster**

An Observationally Driven Multifield Approach for Probing the Circum-Galactic Medium with Convolutional Neural Networks

The circum-galactic medium (CGM) can feasibly be mapped by multiwavelength surveys covering broad swaths of the sky. With multiple large datasets becoming available in the near future, we develop a likelihood-free Deep Learning technique using convolutional neural networks (CNNs) to infer broad-scale properties of a galaxy's CGM and its halo mass for the first time. Using CAMELS (Cosmology and Astrophysics with MachinE Learning Simulations) IllustrisTNG, SIMBA, and Astrid, we train CNNs on 2D maps of Soft X-ray and 21-cm (HI) radio to trace hot and cool gas, respectively, around galaxies, groups, and clusters. The tested CNN provides inferences on halo mass, CGM mass, metallicity, temperature, and cool gas fraction. Our CNN creates the unique opportunity to simultaneously train and test with HI and X-ray maps as a "multifield" dataset, inferring CGM properties significantly better than either alone. Applying multiwavelength survey limits to the CNN shows that X-ray is not powerful enough to infer low halo masses. Creating a multifield with HI is essential for inference refinement. Generally, a CNN trained and tested on Astrid (SIMBA) can most (least) accurately infer CGM properties. Cross-simulation analysis – raining on one simulation and testing on another – is then performed to quantify model robustness. Models that are not robust within cross-simulation analysis will not produce robust inferences when the simulation-based testing set is exchanged with multiwavelength observational data. Future efforts including saliency analysis, higher resolution maps, and a more extensive multifield are underway to overcome this challenge.

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Session Classification: Posters

Track Classification: Online