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# Finding analogues of observed galaxy groups and clusters in cosmological simulations with contrastive learning

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Galaxy groups and clusters are dynamical sites of galaxy evolution and cosmological structure formation. In particular, the intracluster and intragroup media are the hot, volume-filling gas between the galaxies in these deep potential wells. They host signatures of feedback from AGN, non-thermal processes like cosmic ray diffusion and turbulent motion, and mergers with other large structures. The past few years have finally seen suites of cosmological simulations that produce thousands of galaxy clusters, and even more galaxy groups, in realistic cosmic environments and with realistic feedback processes. Matching these to observed systems is, however, an arduous process, because the identifying features are extended and hard to summarise. Contrastive learning is a powerful tool in computer vision, wherein sets of images of one object - augmented by rotation and zooms - are contrasted against sets of images of other objects. The underlying neural network aims to minimise the distance between images in the same set, while maximising the distance to images in a different set. We harness this technique to find analogues observed of galaxy groups and clusters with telescopes like Chandra, XMM-Newton and eROSITA in the TNG-Cluster suite of simulations, the largest ensemble of high-resolution simulations of galaxy clusters in a cosmological context to date. We present the detected analogues to several iconic galaxy clusters, and show how these analogues can be used for inferring parameters relating to cosmology, plasma physics, and galactic feedback.

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