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Weighing the Dark and Light in Cosmology with Machine Learning[1]

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Galaxy clusters contain large amounts of cold dark matter, hot ionized gas, and tens to hundreds of visible galaxies. They are the largest gravitationally bound systems in the Universe and make excellent laboratories for studying cosmology and astrophysics. Historically, Fritz Zwicky postulated the existence of dark matter when he inferred the total mass of the nearby Coma Cluster from the motions of its galaxies and found it to be much larger than the visible mass. Nowadays, the abundance of clusters as a function of mass and time can be used to study structure formation and constrain cosmological parameters. Dynamical measurements of the motions of galaxies can be used to probe the entire mass distribution, but standard analyses yield unwanted high mass errors. First, we show that modern machine learning algorithms can improve mass measurements by more than a factor of two compared to using standard scaling relations. Support Distribution Machines are used to train and test on the entire distribution of galaxy velocities to maximally use available information. Second, we discuss how Deep Learning can be used to train on multi-wavelength images of galaxies and clusters and to predict the underlying total matter distribution. By applying machine learning to observations and simulations, we can map out the dark and light in the Universe.

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