Constraining Models of Galaxy Formation with Lyman-Alpha Absorption around Halos

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Abstract

Galaxy formation depends critically on the physical state of gas in the circumgalactic medium (CGM) and its interface with the intergalactic medium (IGM), determined by the complex interplay between inflow from the IGM and outflows from supernovae and/or AGN feedback. The average Lyman-alpha absorption profile around galactic halos represents a powerful tool to probe their gaseous environments. We compare predictions from hydrodynamical simulations (Illustris, Nyx, Mufasa, Simba) with the observed absorption around foreground quasars, damped Ly-alpha systems, and Lyman-break galaxies. We show how large-scale BOSS and small-scale quasar pair measurements can be combined to precisely constrain the absorption profile over three decades in transverse distance (20 kpc - 20 Mpc). Far from galaxies (> 2 Mpc), the simulations converge to the same profile and provide a reasonable match to the observations. This asymptotic agreement arises because the LCDM model successfully describes the ambient IGM and represents a critical advantage of studying the mean absorption profile. However, significant differences between the simulations, and between simulations and observations, are present on scales 20 kpc - 2 Mpc, illustrating the challenges of accurately modeling and resolving galaxy formation physics. It is noteworthy that these differences are observed as far out as _˜2 Mpc, indicating that the "sphere of influence" of galaxies could extend to approximately _˜7 times the halo virial radius. Recent and ongoing observations (e.g., BOSS, CLAMATO survey) are very precise on these scales and can thus strongly discriminate between different galaxy formation models. We demonstrate that the Ly-alpha absorption profile is primarily sensitive to the underlying temperature–density relationship of diffuse gas around galaxies, and argue that it thus provides a fundamental test of galaxy formation models. Such a test should be adopted by simulators to increase the accuracy of feedback prescriptions and thus the predictive power of their simulations.

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