

Astrophysics > Cosmology and Extragalactic Astrophysics

A Comprehensive Analysis of Uncertainties Affecting the Stellar Mass - Halo Mass Relation for $0 < z < 4$

Peter S. Behroozi (1), Charlie Conroy (2), Risa H. Wechsler (1) ((1))

KIPAC, Stanford University; (2) Princeton University)

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We conduct a comprehensive analysis of the relationship between central galaxies and their host dark matter halos, as characterized by the stellar mass-halo mass (SM-HM) relation, with rigorous consideration of uncertainties. Our analysis focuses on results from the abundance matching technique, which assumes that every dark matter halo or subhalo above a specific mass threshold hosts one galaxy. We discuss the quantitative effects of uncertainties in observed galaxy stellar mass functions (GSMFs) (including stellar mass estimates and counting uncertainties), halo mass functions (including cosmology and uncertainties from substructure), and the abundance matching technique used to link galaxies to halos (including scatter in this connection). Our analysis results in a robust estimate of the SM-HM relation and its evolution from $z=0$ to $z=4$. The shape and evolution are well constrained for $z < 1$. The largest uncertainties at these redshifts are due to stellar mass estimates; however, failure to account for scatter in stellar masses at fixed halo mass can lead to errors of similar magnitude in the SM-HM relation for central galaxies in massive halos. We also investigate the SM-HM relation to $z=4$, although the shape of the relation at higher redshifts remains fairly unconstrained when uncertainties are taken into account. These results will provide a powerful tool to inform galaxy evolution models. [Abridged]

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