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A Comprehensive Study of the Galaxy Stellar Mass-to-Dark Matter Halo Mass Relationship Since z˜5 Using Multi-wavelength Data from UDS and COSMOS Fields

We present a detailed analysis of the galaxy stellar mass-to-dark matter halo mass relationship (SHMR) since z˜5 (˜1 billion years after the Big Bang). This fundamental component of the galaxy-dark matter halo connection was constrained using the measurements of galaxy clustering and abundance in the legacy UDS and COSMOS fields (total effective area ˜1.6 deg²) within the context of dark matter halo occupation distribution (HOD) modeling. Central to our study is the public release of the deepest near-infrared ground-based multiwavelength catalog in the UDS field (24 bands; u-to-IRAC), covering ˜0.9 deg², which includes ˜200,000 objects with robust photometry out to z˜8. This catalog, constructed in homogeneity with the pre-existing Ultra-VISTA (DR3) catalog in the COSMOS field, was essential in avoiding systematic discrepancies of heterogeneous datasets, which convolute the resulting SHMR. Furthermore, using two large and widely separated fields (UDS and COSMOS) allowed us to greatly reduce the impact of cosmic variance, especially as COSMOS has known over-dense structures present at z <˜ 1.5. We show that relying on COSMOS alone for deriving SHMR, as has been done by many preceding studies, can greatly skew the estimates of SHMR.

Additionally, to address the weak constraining power of the high redshift (z > 2) data due to the shrinking dynamical range in stellar mass where the sample is complete, we introduce a novel Bayesian HOD fitting approach. We jointly fit data in all redshift bins where HOD parameters in neighboring redshift bins are connected via physically motivated continuity (smoothing) priors. This allowed us to dramatically plummet the uncertainties in the SHMR at high-z, compared to many similar preceding studies. The error on the log of halo mass with peak integrated star-forming efficiency (SFE) shrunk by up to a factor of ˜ 6 at z > 3, compared to a recent study, greatly unveiling the SHMR at high-z.

Overall, our findings show that star formation is tightly coupled to halo mass; the halo mass with peak SFE (˜ 10ˆ12.4 M⊠) fluctuates only by ˜ 0.2 dex since z ˜ 5. We also observe "downsizing" in the stellar mass buildup within halos (both within central and satellite galaxies), where the most massive halos and galaxies formed their stars earlier, followed by progressively smaller systems. These results provide key insights into the galaxy-dark matter halo connection and the evolution of SFE across cosmic time.

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