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The PAU Survey: the i-band galaxy luminosity function from the present day to $z = 2$, implications for the galaxy-halo connection

We present a measurement of the i-band galaxy luminosity function (LF) from the present day to $z = 2$, using over 1.1 million galaxies from the Physics of the Accelerating Universe Survey (PAUS). PAUS combines broad-band imaging from the Canada–France–Hawaii Telescope Lensing Survey with narrow-band photometry from PAUCam, enabling high-precision photometric redshifts with an accuracy of $\sigma_{68}(\Delta z) = 0.019$ down to $i_{AB} = 23$. A synthetic lightcone mock catalogue built with the GALFORM semi-analytic model applied to the Planck Millennium N-body simulation is used to simulate PAUS selection effects and photometric uncertainties, and to derive a machine-learning estimate of the k-correction. Rest-frame luminosities are recovered using a random forest regressor trained on simulated ugriz photometry and redshifts, and LFs are estimated with the $1/V_{max}$ method and validated against the mock. We find good agreement between observations and models at $z < 1$, with increasing discrepancies at higher redshift driven by photometric redshift outliers. The bright end flattens with redshift, primarily as a consequence of redshift errors, while the faint end becomes progressively more incomplete yet remains useful for constraining models. Analysing red and blue galaxies separately, the model overpredicts the abundance of faint galaxies in both populations. Because the LF is the one-point statistic that anchors the galaxy-halo connection, these results carry directly into how galaxies are assigned to haloes: photometric redshift errors propagate into both the inferred luminosity and V_{max} , systematically distorting the recovered abundances and hence biasing halo occupation inference unless they are forward-modelled. Looking ahead, narrow-band surveys of this kind measure the faint-end abundance across a wide redshift baseline, the regime where alternatives to cold dark matter predict a suppressed halo mass function, offering a route to constrain the nature of dark matter, provided the degeneracy with baryonic feedback is controlled using realistic galaxy formation models.

Primary author: KOONKOR, Suttikoon (National Astronomical Research Institute of Thailand)