R09a A fundamental test for stellar feedback recipes in galaxy simulations

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Direct comparisons between high resolution galaxy simulations and high resolution observations are strong tools to investigate the cloud-scale physics of star formation and feedback in nearby galaxies. Here we carry out such a comparison for hydrodynamical simulations of a Milky Way-like galaxy, including stochastic star formation, H II region and supernova feedback, and chemical post-processing at 8 pc resolution. Our simulation shows excellent agreement with almost all kpc-scale and larger observables, including total star formation rates, radial profiles of CO, H I, and star formation through the galactic disc, mass ratios of the ISM components, both whole-galaxy and resolved Kennicutt-Schmidt relations, and giant molecular cloud properties. However, we find that our simulations does not reproduce the observed de-correlation between tracers of gas and star formation on $\lesssim$ 100 pc scales, known as the star formation uncertainty principle. We conclude that the discrepancy is driven by insufficiently-strong pre-supernova feedback in our simulation, which does not disperse the surrounding gas completely, leaving star formation tracer emission too strongly associated with dense gas tracer emission, inconsistent with observations. This result suggests that cloud-scale de-correlation of gas and star formation is a fundamental test for feedback prescriptions in galaxy simulations, one that can fail even in simulations that reproduce all other macroscopic properties of star-forming galaxies.