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The effect of cosmic rays in the evolution of a Milky Way-like galaxy and its circum-galactic medium

Despite the many successes of cosmological galaxy formation and evolution simulations, they commonly implement baryonic feedback in a phenomenological manner by calibrating “boosting” parameters, which somewhat diminishes their predictive power and restricts their usefulness to interpret observational data. An alternative approach is to improve the modelling of feedback processes from first principles, by self-consistently including components which have by-and-large been overlooked, like radiation, magnetic fields and cosmic rays (CRs). We study the influence of CRs injected by supernovae (SN) in the interstellar medium (ISM) and their impact on the launching of outflows in a cosmological zoom simulation of a Milky Way-like galaxy. We find that, in the same way as artificially boosting SN feedback does, including CRs decreases the stellar mass by 1 dex at high redshift and about a factor 4 at lower redshift as compared to pure hydrodynamical and magneto-hydrodynamical simulations, bringing our galaxy in better agreement with abundance-matching models. This significant suppression of star formation originates from a combination of the ability of CRs to deplete cold, high-density, star-forming ISM gas and a higher proportion of SN energy being injected in low-density gas. Consistent with previous results in the literature, we also find enhanced, multi-phase outflows, with warm ionised gas dominating the mass budget, a large contribution of warm neutral and cold gas at high redshift, and all outflow phases experiencing further acceleration by CR pressure outside of the galaxy. CRs also largely alter the thermodynamical state of the circum-galactic medium, making it colder and denser and slowing down the filamentary inflow of pristine gas provided by the cosmic web. Overall, CRs drastically change the evolution of our Milky Way-like galaxy, particularly at high redshift, pointing to their potentially fundamental role in shaping galaxy formation.