New radiative transfer methods in numerical simulations of galaxy formation

Simulations of the epoch of reionisation often rely on the M1 approximation for radiative transfer due to its simplicity, computational efficiency, and generally accurate approximation of photon flux. However, the M1 model faces challenges in certain regimes, particularly in the optically thin limit, and can introduce artifacts such as pseudo-sources and altered directionality in photon flux interactions (Wu et al., 2009), and the impact of these issues in large simulations where the model is used is still generally uncertain. To address these limitations, we explore an alternative moment-based model, Pn, and evaluate its performance using a suite of four standardized test cases for cosmological radiative transfer models (Iliev et al., 2006). Our results demonstrate that Pn (n>=9) successfully resolves the key issues associated with M1 while maintaining comparable performance in regimes where M1 excels. Furthermore, we highlight that Pn offers improved accuracy in scenarios where M1 may introduce significant biases, potentially impacting the fidelity of reionisation simulations. Although Pn comes with increased computational costs and oscillatory behaviour in a few specific scenarios such as the presence of sharp discontinuities in the environment, its ability to address critical shortcomings of M1 makes it a promising and viable alternative for advancing radiative transfer modelling in cosmological contexts.