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Predicting gravitational wave signals in cosmological simulations of galaxy formation with Arepo-GW

We present a new method for incorporating gravitational wave (GW) sources into cosmological simulations of galaxy formation. Our approach, implemented in the moving-mesh code Arepo, associates the properties of merging binary systems –black hole-black hole, black hole-neutron star, and neutron star-neutron star – with star particles representing a single stellar population (SSP) in cosmological simulations. This association is performed through stochastic sampling of binary merger events, as predicted by state-of-the-art stellar evolution models (e.g., MOBSE or SEVN), and is based on the local properties of the SSP, such as metallicity and age.

Our method can operate in two modes: (i) on-the-fly, generating GW events as a galaxy formation simulation progresses, and (ii) in post-processing, tracking back the evolution of stellar particles based on their properties starting at any given redshift for which a snapshot is available. Recently, we applied this approach to the flagship simulation of the Millennium-TNG suite –one of the largest hydrodynamical galaxy formation simulations to date, with a box size of 0.5 Gpc/h –and we will present the properties of the resulting GW event catalogue. Our tool can be extended to also process snapshots beyond the native Arepo format, making it broadly adaptable. This flexibility enables more realistic GW event predictions, which can be used to validate analysis pipelines for cosmological constraints using dark sirens, among other applications.

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