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Emulating 2-body decaying dark matter with neural networks

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The exact nature of dark matter (DM) remains still unknown and 2-body decaying dark matter model, one of the minimal extensions of standard cold dark matter model (ΛCDM), has been shown to be an interesting dark matter candidate, namely for a potential of relaxing a famous σ_8-tension. Moreover, there have even been studies reporting a preference of this model over standard ΛCDM. In this model, DM particles decay into a dark radiation and stable daughter particles receiving a velocity kick as a consequence of decay. A well-established way of simulating such a model is using an N-body code. However, directly running N-body simulations within an MCMC framework is computationally prohibitive even on most powerful machines existing. Therefore, it is inevitable to have a faster prediction method bypassing the N-body part of the forward modelling.

In our work, we combine two Machine Learning-based techniques to build up a fast prediction tool for inferring nonlinear effects of 2-body decaying dark matter. First, we run $\sim$100 N-body simulations using *Pkdgrav3* to obtain the matter power spectrum up to very small scales. We then compress the data using Principal Component Analysis and train sinusoidal representation networks (SIRENs) that can produce the nonlinear power spectra which we call an emulator. This emulator can probe the model in consideration for various redshifts, spatial scales and three 2-body decaying dark matter parameters. Our architecture can emulate the dark matter impact with error below 1% for both $1-$ and $2-\sigma$ limits, meeting the requirements of most of the currently ongoing and planned probes, such as *KiDS-1000*, *DES* and *Euclid*. We also present constraints for 2-body decaying dark matter model derived from the latest observations, namely *KiDS-1000* and *Planck 2018*.

Auteur principal: BUCKO, Jozef (Institute for Computational Science, University of Zurich)

Co-auteurs: Prof. SCHNEIDER, Aurel (Institute for Computational Science); Dr GIRI, Sambit (Institute for Computational Science, University of Zurich)

Orateur: BUCKO, Jozef (Institute for Computational Science, University of Zurich)

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