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Generative Adversarial Networks for Approximating the Chameleon Scalar Field

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One of the main challenges in numerical cosmology is the difficulty of producing large scale, high resolution simulation data, especially when exploring novel cosmological models. Producing physical simulations on cosmological scales with enough detail to resolve galaxy-formation scale physics is very computationally expensive. In this work, I train a generative adversarial network (GAN) to quickly approximate the scalar field potential predicted by the theory of chameleon gravity, a possible dark energy candidate. The chameleon is a hypothetical scalar particle which has an effective mass that depends strongly on the local energy density, meaning that a fifth force mediated by such a particle would be small on Earth and large in low-density intergalactic regions. The dependence of the chameleon on the local density means it could be coupled to mass with a strength on the order of that of gravity, while remaining unseen so far in tests of the equivalence principle on Earth. A fast and accurate solver for this fifth force potential will allow the incorporation of the chameleon field into both large N-body simulations, as well as simulations of table-top fifth force experiments. After training a GAN on 2-dimensional chameleon field data produced using iterative matrix inversion, I find that the generative network is able to calculate the chameleon field from new initial mass distributions significantly faster than other computational methods, with a pixel to pixel error on the order of a few percent. With some tweaks, these results show a promising method for speeding up cosmological simulations including fifth force potentials, and possibly for directing future terrestrial experiments searching for evidence of the chameleon particle.

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