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Acausality in Superfluid Dark Matter and MOND-like Theories

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There has been much interest in novel models of dark matter that exhibit interesting behavior on galactic scales. A primary motivation is the observed Baryonic Tully-Fisher Relation in which the mass of galaxies increases as the quartic power of rotation speed. This scaling is not obviously accounted for by standard cold dark matter. This has prompted the development of dark matter models that exhibit some form of so-called MONDian phenomenology to account for this galactic scaling, while also recovering the success of cold dark matter on large scales. A beautiful example of this are the so-called superfluid dark matter models, in which a complex bosonic field undergoes spontaneous symmetry breaking on galactic scales, entering a superfluid phase with a 3/2 kinetic scaling in the low energy effective theory, that mediates a long-ranged MONDian force. In this work we examine the causality and locality properties of these and other related models. We show that the Lorentz invariant completions of the superfluid models exhibit high energy perturbations that violate global hyperbolicity of the equations of motion in the MOND regime and can be superluminal in other parts of phase space. We also examine a range of alternate models, finding that they also exhibit forms of non-locality.

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