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A TDiff invariant scalar field theory: breaking and restoring the symmetry

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We reflect on the possibility of breaking the diffeomorphism (Diff) invariance in the gravitational couplings of matter down to only transverse diffeomorphisms (TDiff), and study the consequences on a scalar field theory. We then explore the possibility of restoring the full Diff invariance preserving the locality of the theory by the introduction of an additional vector field. From the equivalent fluid description, we find that the reformulation with the full symmetry allows us to find the expression for the effective speed of sound of general TDiff models. This result provides us with physically reasonable conditions that should be satisfied by the coupling functions. We finally consider some particular cases of interest, such as adiabatic models, constant equation of state models, or models presenting different gravitational domains (characterized by the focusing or possible defocusing of time-like geodesics), which could be used to unify the dark sector.

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