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A systematic procedure to build the beyond generalized Proca field theory

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To date, different alternative theories of gravity involving Proca fields have been proposed. Unfortunately, the procedure to obtain the relevant terms in some formulations has not been systematic or exhaustive, thus resulting in some missing terms or ambiguity in the process carried out. In this paper, we propose a systematic procedure to build the beyond generalized theory for a Proca field in four dimensions containing only the field itself and its first-order derivatives. In our approach, we employ all the possible Lorentz-invariant Lagrangian pieces made of the Proca field and its first-order derivatives, including those that violate parity, and find the relevant combination that propagates only three degrees of freedom and has healthy dynamics for the longitudinal mode. The key step in our procedure is to retain the flat space-time divergences of the currents in the theory during the covariantization process. In the curved space-time theory, some of the retained terms are not current divergences anymore so that they induce the new terms that identify the beyond generalized Proca field theory. The procedure constitutes a systematic method to build general theories for multiple vector fields with or without internal symmetries. We also comment on the possibility of obtaining the beyond generalized SU(2) Proca field theory from our procedure.

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