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Perturbative unitarity and Goldstone effective field theory in modified Genesis

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We develop a manifestly conformal-frame-independent approach to assessing perturbative unitarity and apply it to modified Genesis in a $G_2 + G_3$ Horndeski model. The construction uses an effective metric determined by the tensor quadratic action, its associated conformal time, and canonically normalized scalar perturbations. We determine the quadratic coefficients and scalar sound speed, analyze linear stability, and express the scalar cubic action in frame-invariant variables, retaining interactions generated by time-dependent canonical normalization. Power counting identifies potentially restrictive interactions and estimates their characteristic scales relative to the background evolution scale in the asymptotic past.

We then compute the tree-level scalar-exchange contribution to $2 \rightarrow 2$ scattering in a local high-energy approximation. Explicit cancellations among the nominally leading interactions demonstrate the limitations of estimates based on individual operators. The retained leading exchange amplitude contains only the $\ell = 0$ and $\ell = 2$ partial waves, and we evaluate these projections to estimate the perturbative validity range and its dependence on the scalar sound speed.

As a complementary description of the scalar sector, we derive the cubic Goldstone action for the relevant unitary-gauge effective-field-theory operators on a fixed FLRW background, retaining the time dependence of their coefficients and the interactions generated by restoring time diffeomorphisms.

Primary author(s) : EVAROVSKAYA, Zlata (Moscow State U.); AGEEVA, Yulia (Moscow, INR); PETROV, Pavel (IBS, Daejeon, CTPU)

Presenter(s) : EVAROVSKAYA, Zlata (Moscow State U.)

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