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Scattering Amplitudes of Massive Spin-2 Kaluza-Klein States with Matter

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We perform a comprehensive analysis of the scattering of matter and gravitational Kaluza-Klein (KK) modes in five-dimensional gravity theories. We consider matter localised on a brane and in the bulk of the extra dimension for scalars, fermions and vectors, respectively and consider an arbitrary warped background. While naive power-counting suggests that there are amplitudes that grow as fast as $\mathcal{O}(s^3)$ [where s is the centre-of-mass scattering energy-squared], we demonstrate that cancellations between the various contributions result in a total amplitude which grows no faster than $\mathcal{O}(s)$. Extending previous work on the self-interactions of the gravitational KK modes, we show that these cancellations occur due to sum-rule relations between the couplings and the masses of the modes that can be proven from the properties of the mode equations describing the gravity and matter wavefunctions. We demonstrate that these properties are tied to the underlying diffeomorphism invariance of the five-dimensional theory. We discuss how our results generalise when the size of the extra dimension is stabilised via the Goldberger-Wise mechanism. Our conclusions are particularly relevant for freeze-out and freeze-in relic abundance calculations for dark matter models, including a spin-2 portal arising from an underlying five-dimensional theory.

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