“Unification from Scattering Amplitudes”

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The modern S-matrix program offers an elegant approach to bootstrapping quantum field theories without the aid of an action. While most progress has centered on gravity and gauge theory, similar ideas apply to effective field theories (EFTs). Sans reference to symmetry or symmetry breaking, we show how certain EFTs can be derived directly from the properties of the tree-level S-matrix, carving out a theory space of consistent EFTs from first principles. Furthermore, we argue that the S-matrix encodes a hidden unification of gravity, gauge theory, and EFTs. In particular, starting from the tree-level S-matrix of the mother of all theories, gravity, we derive the S-matrices of gluons, pions, Galileons, and Born-Infeld photons. Many attributes of EFTs like soft theorems and double copy relations are revealed as inherited traits. At the level of the action, this procedure is equivalent to a peculiar version of dimensional reduction, and applied to Yang-Mills theory yields a new action for the nonlinear sigma model comprised of purely cubic interactions. Physically, this recasts pions as gluons in higher dimensions. This representation manifests an explicit duality between flavor and kinematics, and the square of this action yields a new action for the Galileon.