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Fractons from covariant higher-rank Chern-Simons and BF theories

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Fracton phases of matter constitute an interesting point of contact between condensed matter and high-energy physics. The limited mobility of subdimensional quasiparticles finds applications in different areas of theoretical physics, including quantum information, quantum field theory, elasticity, hydrodynamics and gravity. In our works we adopt a field theoretical approach to investigate three dimensional (3D) actions involving a rank-2 symmetric tensor gauge field $a_{\mu\nu}(x)$ invariant under the covariant fracton symmetry. First of all we study the most general 3D action of $a_{\mu\nu}(x)$ with mass dimension one and the theory appears as a traceless non-topological higher-rank generalisation of the ordinary Chern-Simons model. Once matter is introduced, our model shows a Hall-like dipole current together with a vectorial "flux-attachment" relation for dipoles. Subsequently, we studied the 3D field theory of two tensor gauge fields with mass dimension one: $a_{\mu\nu}(x)$, transforming under the covariant fracton symmetry, and $B_{\mu\nu}(x)$, with no symmetry on its indices. The corresponding invariant action is a non-topological higher-rank BF-like model, first considered from a purely field theoretical point of view, and the propagators with their poles and the degrees of freedom are studied. Once matter is introduced, a subdimensional behaviour emerges, with both fractons and lineons. Moreover our theory can be mapped to the low-energy effective field theory describing the Rank-2 Toric Code. Finally we analyze the case in which $B_{\mu\nu}(x)$ is a symmetric tensor, where it turns out that the action can be cast into the sum of two rank-2 Chern-Simons actions, thus generalizing the ordinary abelian case.

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