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# Topology in multilevel systems and non-Abelian Floquet braiding

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A significant fraction of topological materials has been characterized using symmetry requirements of wave functions. The past three years, however, have witnessed the rise of novel multi-gap dependent topological states, the properties of which go beyond these approaches and are yet to be fully explored. While such systems are thus of active interest already in static settings, most physical phenomena are in fact dynamical in nature. We show that the combination out-of-equilibrium processes and these recent multi-gap topological insights galvanize a new direction within topological phases of matter. We present that periodic driving can induce anomalous multi-gap topological properties that have no static counterpart. In particular, we identify Floquet-induced non-Abelian braiding, which in turn leads to a phase characterized by an anomalous Euler class, the prime example of a multi-gap topological invariant. Most strikingly, we also retrieve the first example of an 'anomalous Dirac string phase'. This gapped out-of-equilibrium phase features an unconventional Dirac string configuration that physically manifests itself via anomalous edge states on the boundary. Our results therefore not only provide a stepping stone for the exploration of intrinsically dynamical and experimentally viable multi-gap topological phases, but also demonstrate a powerful way to observe these non-Abelian processes notably in quantum simulators.

Moreover, many of these topological evaluations are related to the underlying quantum geometry, for which the Bloch sphere constitutes a paradigmatic visual aid for the minimal two levels. Multilevel systems however offer unique opportunities, in view of topological considerations as well as quantum information applications such as with qudits. Although similar hypersphere descriptions for higher dimensional Hilbert spaces exist theoretically, they naturally become less intuitive as the complexity increases. We here introduce a geometric description for N-level quantum systems in terms of a nested structure comprising spheres, which brings a long-sought-after intuitive geometric picture. This opens up a new avenue for the interpretation of the topological classification and the dynamical illustration of multilevel systems as well as the design of new experimental probes.

Slager, Bouhon, Ünal, arXiv:2208.12824.
Kemp, Cooper, Ünal, Phys Rev Research 4, 023120 (2022).

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