Topological states in synthetic dimensions

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Topological insulators are materials which have insulating interiors but conducting edge states [1]. As the existence of such edge states is due to a non-trivial topological invariant, they are robust with respect to disorder.

There recently has been a large-scale effort to realise analogues of topological insulators with ultracold atoms. For this case, atoms are to be thought of as the electrons in the material, while standing light waves replace the ionic crystal lattice comprising the solid. The first realisation of topological edge states in an atomic gas was reported recently [2]. The interpretation, however, had a curious twist: the internal spin degrees of freedom of the atoms were thought of as an extra “synthetic” spatial dimension.

In this project, we will analyse this experiment using field-theoretical methods. We will then investigate particular variations of the protocol with an aim to realise other systems of interest like the so-called Weyl semimetal.

A longer term goal will be to investigate the four-dimensional quantum Hall effect, where the spin degrees of freedom play the role of the fourth dimension.