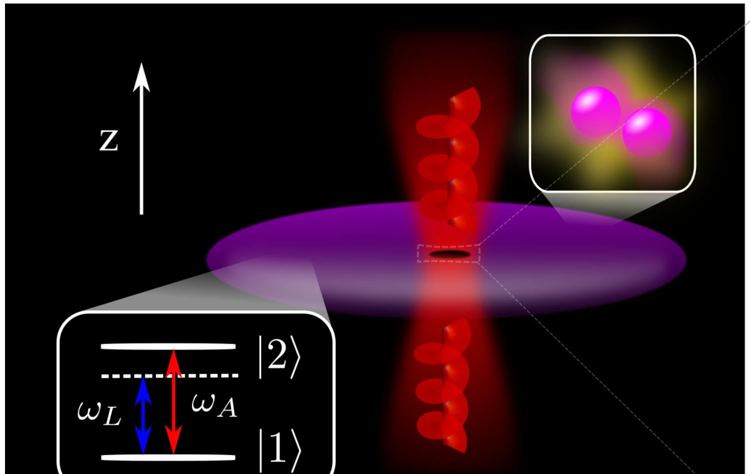
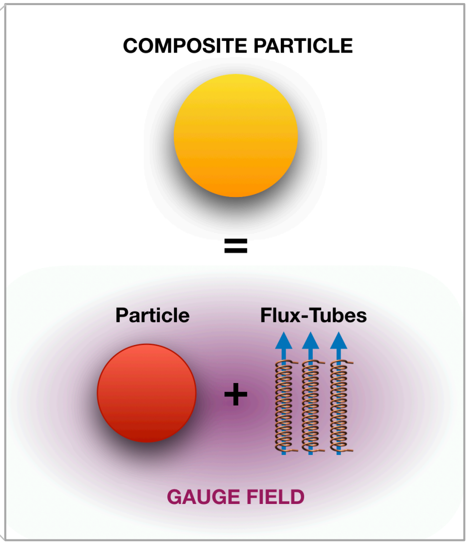
Synthetic Flux Attachment

Author(s): Gerard Valentí-Rojas[1], Niclas Westerberg[2,1], Patrik Öhberg[1]
Institution(s): [1] *SUPA, Institute of Photonics and Quantum Sciences, Heriot-Watt University, UK.* [2] *School of Physics & Astronomy, University of Glasgow*
Funder(s): EPSRC (CM-CDT)

Abstract Gauge potentials that depend on matter density are at the core of topologically ordered states of matter. We find that their generation is equivalent to the emergence of a Chern-Simons term. As a proof of concept, we outline how to synthetically engineer the mechanism that gives rise to the formation of Abelian anyons. We propose that a carefully manufactured Bose-Einstein condensate (BEC) coupled by a laser beam with angular momentum gives rise to a dynamical gauge field that ensures flux attachment.



Laser-induced flux attachment in a two-level atomic BEC with pairwise interactions



Project Description Flux attachment is a mechanism by which charged particles capture magnetic flux quanta and form composite entities. As a consequence of flux dressing, these composites may acquire fractional quantum numbers (*e.g.* electric charge) and statistics.
Although charge-neutral systems do not couple to vector potentials, geometric (Berry) phases induced in ultracold neutral atoms allow emulating the behaviour of charged particles in electromagnetic fields. These phases can be engineered in Bose-Einstein condensates by means of laser coupling. Suitable interaction of the light-matter system generates an effective singular nonlinear gauge potential. Such emergent field performs a laser-tuned version of flux attachment. Then, anyonic vortices are formed and we effectively describe the condensate as a fractional quantum Hall fluid.

Key Results

- A singular density-dependent Berry connection is identified as a Chern-Simons term responsible for flux attachment.
- An example of a topological gauge theory can be quantum simulated with one species of atoms only.
- Phenomena found in strongly correlated materials, *e.g.* fractional quantum hall physics, can be achieved in dilute, weakly interacting, well-controlled systems.
- Additional coupling of internal levels is believed to lead to formation of skyrmions, while generalisation to a non-Abelian gauge group is relevant for topological quantum computing and gravity in low dimensions.

This work: G. V-R., N. Westerberg, P. Öhberg, arXiv:2003.14339 (2020)