Laughlin-like physics in small subwavelength atom arrays

B. Jaworowski[*1], **D. E. Chang** [1]
1. ICFO (Institute of Photonic Sciences), Mediterranean Technology Park Av. Carl Friedrich Gauss, 3 08860 Castelldefels (Barcelona), Spain

Atom arrays offer exciting possibilities of quantum optics, such as harnessing wave interference and collective absorption/emission to, e.g., increase the efficiency of quantum optical devices beyond standard limits. The current frontier in array physics is the many-body regime, where complex effects are expected due to interaction between atomic excitations. To find intuitions about the behavior of such systems, one can seek for analogous solid-state systems for which the many-body problem was already thoroughly studied.

In this work, we propose that the low-energy physics of small hexagonal flakes of three-level atoms in magnetic field can be understood in analogy to the fractional quantum Hall systems. It was shown that in arrays of three-level atoms, magnetic field can induce a topologically nontrivial single-particle band structure. If such topological bands are flat enough, they may host fractional quantum Hall states on the many-particle level. Here, we show that at small lattice constant and in presence of parabolic confinement potentials, small hexagonal flakes of honeycomb three-level atom arrays exhibit a characteristic branch in the few-particle spectrum, resembling the edge spectrum on the top of the $\nu = 1/2$ Laughlin state and exhibiting high overlap with model Laughlin states. Although the band structure of an infinite lattice exhibits divergences near the light cone, finite-size effects smooth out these divergencies, and, as a result, small flakes dominated by near-field interaction behave similarly to a topological flat-band system. We evaluate the decay rates of the Laughlin-like states, showing that some of them are highly superradiant, while some exhibit subradiance. Then, we study the behavior of the system under driving by Laugerre-Gauss beams.

[*]blazej.jaworowski@icfo.eu