Localization and Condensation in Fractal and Hyperbolic Lattices

Tobias Grass
K. Dutkiewicz, M. Płodzień, A. Rojo-Francàs, P. Pansari, U. Bhattacharya, B. Juliá-Díaz, M. Lewenstein

DIPC, Manuel Lardizabal 4, Donostia/San Sebastián, Spain

Tobias.grass@dipc.org

This talk explores how unconventional lattice connectivity—from self-similar fractals to negatively curved hyperbolic graphs—reshapes quantum phenomena on the single- and many-body level. Geometric tuning enables transport regimes ranging from sub-diffusive to localized, governed by the interplay of fractal dimension and level-spacing distributions. In bosonic systems, hyperbolic curvature allows 2D lattices to mimic the Bose-Einstein condensation of 3D cubic systems, whereas fractal structures suppress condensation and can trigger condensate fragmentation. These geometric effects extend to the strongly interacting regime, where the fractal dimensionality reflects in the boundaries of the Mott insulating phase.

References

[1] T. Graß, D. Bercioux, U. Bhattacharya, M. Lewenstein, H. S. Nguyen, and C. Weitenberg, Colloquium: Synthetic quantum matter in nonstandard geometries, Rev. Mod. Phys. 97, 011001 (2025).

[2] A. Rojo-Francàs, P. Pansari, U. Bhattacharya, B. Juliá-Díaz, and T. Graß, Anomalous quantum transport in fractal lattices, Commun. Phys. 7, 259 (2024).

[3] K. Dutkiewicz, M. Płodzień, A. Rojo-Francàs, B. Juliá-Díaz, M. Lewenstein, and T. Graß, Bose-Einstein condensation in exotic lattice geometries, Phys. Rev. A 113, 013320 (2026)