Visualization of multifractal superconductivity in a two-dimensional transition metal dichalcogenide in the weak-disorder regime

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Eigenstate multifractality is a distinctive feature of non-interacting disordered metals close to a metal-insulator transition, whose properties are expected to extend to superconductivity. While multifractality in three dimensions (3D) only develops near the critical point for specific strong-disorder strengths, multifractality in quasi-two dimensional (2D) systems with spin-orbit coupling is expected to be observable even for weak disorder. Here we investigate the impact of multifractality on the superconducting state [1] of an intrinsic weakly disordered single-layer of $NbSe_2$ by means of low-temperature scanning tunneling microscopy/spectroscopy (STM/STS) [2]. The superconducting gap, characterized by its width, depth and coherence peaks amplitude, shows characteristic spatial single-wavelength modulation nearly coincident with the periodicity of the quasiparticle interference pattern observed at the Fermi energy. Spatial inhomogeneity of the superconducting gap width, which is proportional to the local order parameter in the weak disorder regime, shows a characteristic log-normal statistical distribution as well as a power-law decay of the two-point correlation function, in agreement with our theoretical model. This novel state is universal and governs the properties of even weakly disordered 2D superconductors with spin-orbit coupling. This offers a novel platform to tune and ultimately control superconductivity in novel 2D quantum materials.

References

[1] M. M. Ugeda, et al., Nature Physics 12, 92 (2016).
[2] C. Rubio-Verdú, et al, submitted (2019).

Figures

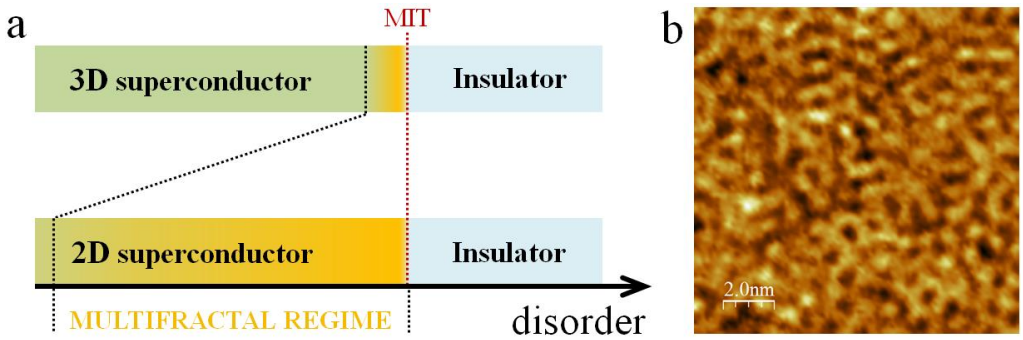

Figure 1. a. Sketch of the extent of the multifractal regime in the superconducting state in 3D and 2D. b. Spatial distribution of the superconducting order parameter in a 12 nm x 12 nm region of single-layer $NbSe_2$.