Strong quantum scars and measures of chaos in disordered quantum dots

P. J. J. Luukko[1], J. Keski-Rahkonen[2], E. J. Heller[3], E. Räsänen[2]

[1]Department of Physics, University of Jyväskylä, Jyväskylä FI-40014, Finland
[2]Department of Physics, Tampere University of Technology, Tampere FI-33101, Finland
[3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA
email: joonas.keski-rahkonen@tut.fi

Quantum scars are enhancements of probability density in the eigenstates of a quantum system along short unstable periodic orbits of the corresponding *chaotic* classical system [1]. We have discovered strong quantum scars in two-dimensional quantum dots perturbed by local impurities [2]. These scars (see Fig. 1) are not explained by ordinary scar theory [1]. Instead, they are created by a mechanism that combines classical resonances in the unperturbed system and the local nature of the perturbation [2].

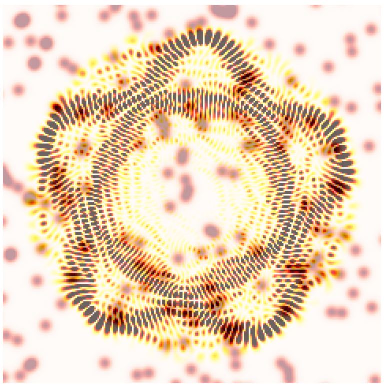

Figure 1: *Example of a strong pentagram-shaped scar in a system with local impurities (red markers).*

Here we focus on the energy level statistics [3] of perturbed quantum dots. This statistical analysis is used to quantify the chaoticity of the systems. To solve the energy spectrum efficiently we use the `itp2d` code [4], which is based on the imaginary time propagating method. In the statistical analysis we employ traditional measures such as the spectral rigidity, but also more modern methods such as detrended fluctuation analysis (DFA). In particular, we study how the chaoticity of the spectrum is connected to the strength of the scarring, and how an external magnetic field affects the eigenvalue statistics and the scarring.

An important future goal is to study how scars can be utilized for quantum transport. We have shown that scars can be exploited to propagate quantum wave packets in the system with very high fidelity [2]. Moreover, the scarring mechanism makes the appearance and orientation of the scars controllable. The main question is whether we can use these properties to enhance the conductance of quantum dots in a controlled way.

[1] E. J. Heller, Phys. Rev. Lett. **53**, 1515 (1984).
[2] P. J. J. Luukko, B. Drury, A. Klales, E. J. Heller, and E. Räsänen, arXiv:1511.04198.
[3] See, e.g., M. L. Mehta, *Random matrices*, 2nd ed. (Academic Press, 1991).
[4] P. J. J. Luukko and E. Räsänen, Comput. Phys. Commun. **184**, 769 (2013).