Phase protection of Fano-Feshbach resonances

Daniel M. Reich[1,2,*], Alexander Blech[1,2], Yuval Shagam[3], Wojciech Skomorowski[2], Nicolas Hölsch[3], Prerna Paliwal[3], John W. Rosenberg[3], Natan Bibelnik[3], Oded Heber[4], Edvardas Narevicius[3], Christiane P. Koch[1,2]

[1]*Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany*

[2]*Theoretical Physics, Universität Kassel, Heinrich-Plett-Strasse 40, 34132 Kassel, Germany*

[3]*Department of Chemical and Biological Physics, Weizmann Institute of Science, Rehovot 76100, Israel*

[4]*Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot 76100, Israel*

[*]danreich@zedat.fu-berlin.de

Fano-Feshbach resonances (FFR) describe the decay of a quantum system due to coupling of quantum mechanical bound states to a continuum of scattering states. They serve as a key mechanism to controlling interactions in ultracold atomic gases. The position of FFR was shown to follow quantum chaotic statistics. In contrast, their lifetimes have so far escaped a similarly comprehensive understanding, despite the intriguing observation of spanning many orders of magnitude. We attribute this phenomenon to phase protection: Any bound state, despite being resonantly coupled to a scattering state, becomes protected from decay whenever the relative phase is a multiple of π. Supported by lifetime measurements of rovibrational FFR, we demonstrate that both the reduced mass and the shape of the potential can significantly influence the occurrence of phase-protected resonances. Our results provide a blueprint for identifying naturally long-lived states in a decaying quantum system.