# Regularization of tunneling rates with quantum chaos

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We study tunneling in various shaped, closed, two-dimensional, flat potential, double wells by calculating the energy splitting between symmetric and anti-symmetric state pairs. We use the boundary and finite element methods for the calculations. For shapes that have regular or nearly regular classical behavior (e.g. rectangular or circular wells) we find that tunneling rates for nearby energy states vary over wide ranges. Rates for energetically close quantum states can differ by several orders of magnitude. As we transition to well shapes that admit more classically chaotic behavior (e.g. the stadium, the Sinai billiard) the range of tunneling rates narrows, often by an order of magnitude. For well shapes in which the classical behavior appears to be fully chaotic (as determined from numerical bounce maps) the tunneling rates' range narrows to about a factor of 4 or so between the smallest and largest rates in a wide range of energies. This dramatic narrowing appears to come from destabilization of periodic orbits in the regular wells that produce the largest and smallest tunneling rates. It is in this sense that we say the quantum chaos regularizes the tunneling rates. We have devised a theory based on a random plane wave approximation that yields tunneling rates in the chaotic systems that match our calculations with no adjustable parameters. These results suggest that it may be possible to control the distribution of tunneling rates as a function of energy in quantum dots and other systems by changing the shape of the dot thereby providing a design tool for nanodevices.