Amphibious Complex Orbits and Dynamical Tunneling

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Quantum tunneling takes place dynamically in mixed-type phase space where invariant tori and chaotic regions coexist. Complex semiclassical analysis reveals that a bunch of tunneling trajectories, not like the instanton in 1-dimensional tunneling, associated with chaos, or more precisely the Julia set in the complex plane, is involved in dynamical tunneling in mixed phase space. An important characteristic of complex orbits, which has been shown in a series of works by Bedford and Smillie, is that they exhibit an amphibious character: they behave as regular orbits when the orbits stay in the regular region while as chaotic orbits when they wander in the chaotic domain. Exactly this character explains the emergence of "amphibious states", the states ignoring the underlying classical invariant structures.