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Symmetry breaking in quantum chaotic systems

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Abstract. We show, using semiclassical methods, that as a symmetry is broken, the transition between universality classes for the spectral correlations of quantum chaotic systems is governed by the same parametrization as in the theory of random matrices. The theory is quantitatively verified for the kicked rotor quantum map. We also provide an explicit substantiation of the random matrix hypothesis, namely that in the symmetry-adapted basis the symmetry-violating operator is random.

Keywords. Quantum chaos; symmetry breaking; intermediate ensembles.

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There is considerable evidence that depending on the exact symmetries, the spectral behavior of chaotic systems can be modeled by one of the various universality classes of random matrices. Most common among these are the Gaussian orthogonal and unitary ensembles, GOE and GUE, and the analogous circular ensemble models COE and CUE [1, 2]. The former pertain to autonomous systems, whereas the latter have application in the study of non-autonomous systems such as quantum maps.

For systems with partly violated symmetry, one requires intermediate ensembles. Dyson [3] introduced Brownian motion ensembles of random matrices for studying small symmetry violations in complex systems. There are many examples in this regard, two of which are considered here, namely the transition from COE to CUE for partial time reversal (T) violation, and the transition from a direct sum of two independent COE's to a single COE of larger dimensionality for partial parity (P) violation. The assumption underlying this theory is that the symmetry violating part of the matrix (the Hamiltonian for autonomous systems and time evolution operator for quantum maps) is random when expressed in a representation in which the symmetry preserving part is diagonal [4, 5]. An important consequence of this is that the spectral correlations undergo a rapid transition from one universality class to another as a (global) symmetry breaking parameter is varied. The speed of the transition is determined by the effective dimensionality (N) of the matrix (N being energy dependent for autonomous systems). The transition itself is smooth when the parameter is scaled by some power of N [4–8]. These results have provided sensitive tests of time-reversal [5] and isospin symmetries in complex nuclei [8, 9], and the LS coupling scheme [10] in complex atoms. Aspects of the transition in spectral correlations have been the subject of some earlier studies on T-violation in quantum chaotic billiards [11–14] and kicked tops [15].

Transitions between universality classes themselves have a universal classification and the purpose of this letter is to establish this fact. We elucidate how features of