Time reversal symmetry breaking: effect on statistics of chaotic wavefunction

Nandan Jha[1*] and Sudhir R. Jain[2]
[1] *High Pressure & Synchrotron Radiation Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[2] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

Introduction

Rotating nuclei have been studied in a great detail, beginning from the cranking model by Inglis [1], and the later work by Bohr and Mottelson [2]. The latter work was brought to conclusion by Jain et al. [3] where they showed that there were three regimes classified by the solutions of the Duffing equation in the angular momentum space. These results have been subsequently used in understanding several aspects of superdeformed nuclei [4, 5]. The adiabatic response of such a system which involves motion of the boundary, is also related to the geometric phase acquired by the single-particle wavefunction [6].

Rotation and vibration of an integrable billiard (square billiard) led us to predict the appearance of a band of narrow resonances about the single particle level. This is a novel mechanism of enhancement of level density due to collective motion [7]. Since the wavefunctions are rather complex, only statistical studies have been possible with very few exceptions [8].

Wavefunction statistics

Considering a square billiard for a model integrable system, and rotate it about a corner with an angular velocity ω. The transition from regular to chaotic dynamics is governed by the parameter $\lambda = 2E/\omega^2$ which depends on the energy, E of the system. It is evident from the studies of classical dynamics and from the study of NNS distribution for lower and higher energy levels at a fixed ω [9–12].

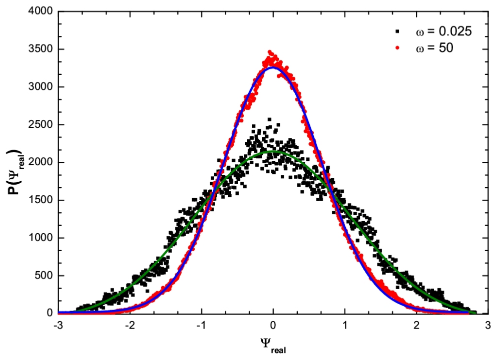

FIG. 1: Histogram of real part of 1000^{th} wavefunction at $\omega = 0.025$ and $\omega = 50.0$

In Fig. 1, the probability distribution functions of ψ_{Real} for $\omega = 0.025$ and $\omega = 50.0$ show that the wavefunctions are chaotic. This is even when the corresponding classical dynamics is mixed, i.e. there is a large fraction of regular region in phase space. To explore this further, we show the probability distribution functions of $|\psi|^2$ (Fig. 2) for $\omega = 0.025$ and $\omega = 50.0$. This makes an important point - as ω varies from 0.025 to large values (say, $\omega = 50$), there is a crossover from a Porter-Thomas distribution to Poisson distribution. This strongly suggests a transition of universality class where time reversal invariance (TRI) holds (Gaussian Orthogonal Ensemble) to Gaussian Unitary Ensemble where TRI breaks.

*Electronic address: nandanj@barc.gov.in

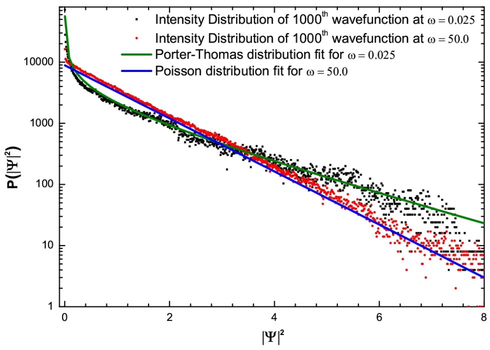

FIG. 2: Histogram of $|\psi|^2$ of 1000^{th} wavefunction at $\omega = 0.025$ and $\omega = 50.0$

Concluding remarks

We have shown here that although the statistics of nearest-neighbouring energy levels (NNS) shows a transition from Poisson (regular) to Wigner distribution (chaotic), the wavefunction statistics reveal further that in addition to chaos, there is a breaking of time reversal symmetry.

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