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Recent results in quantum chaos and its applications to nuclei and particles

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In the last decade or so, the study of chaos in nuclei and other quantum systems has been a very active research field. Besides work based on random matrix theory, new theoretical developments making use of information theory, time series analysis, and the merging of thermodynamics and the semiclassical approximation have been published [1]. In this talk, a survey of chaotic dynamics in atomic nuclei is presented, using on the one hand standard statistics of quantum chaos studies, as well as time series analysis methods. We emphasize the energy and isospin dependence of nuclear chaoticity, based on shell-model energy spectra fluctuations in Ca, Sc and Ti isotopes, which are analyzed using standard statistics such as the nearest level spacing distribution P(s) and the Dyson-Mehta Δ3 statistic [2].
We also discuss quantum chaos in general using a new approach based on the analogy between the sequence of energy levels and a discrete time series. Considering the energy spectrum fluctuations as a discrete time series, we have shown that chaotic quantum systems such as 24Mg and 32Na nuclei, quantum billiards, and random matrix theory (RMT) ensembles, exhibit 1/f noise in their power spectrum [3]. Moreover, we show that the spectra of integrable quantum systems exhibit 1/f2 noise [3]. Therefore we suggest the following conjecture:

The energy spectra of chaotic quantum systems are characterized by 1/f noise.

We have also derived an analytic expression for the energy level fluctuations power spectrum of RMT ensembles, and the results confirm the above conjecture [4].
The order to chaos transition has been studied in terms of this power spectrum for several intermediate systems, such as the Robnik billiard [5], the quartic oscillator or the kicked top [6]. A power law 1/f β is found at all the transition stages, and it is shown that the exponent β is related to the chaotic component of the classical phase space of the quantum system.
This approach has also been applied to study the possible existence of chaos remnants in nuclear masses [7], and to characterize the spectral fluctuations of imperfect spectra, with missing or misassigned levels [8].
Finally, we present a recent study of the low-lying baryon spectrum up to 2.2 GeV which has shown that experimental data exhibit a P(s) distribution close to GOE and, on the contrary, quark models predictions are more similar to the Poisson distribution [9]. This result sheds light on the problem of missing baryon resonances.

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