Localization in $2p1f$ nuclear shell-model wavefunctions

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Abstract

For the study of complexity and chaos in many-particle nuclear wavefunctions in large shell-model basis spaces, the localization length related to the number of principal components is calculated for several Ca, Sc and Ti isotopes, and compared to the predictions of the embedded Gaussian orthogonal ensemble. The large dimensionalities involved, up to many thousands, ensure good statistics, and the agreement is very good in the chaotic region of the spectra. The localization length of shell-model wavefunctions in Ca isotopes is much smaller than in Sc, showing a strong isospin dependence of nuclear chaos, in good agreement with previous results based on energy level fluctuation properties.

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1. Introduction

The study of the eigenvector amplitudes of many-fermion systems and the construction of information entropy, number of principal components and similar measures for the study of complexity and chaos in the system is of great current interest. Firstly the investigation of Izrailev [1] and then results from detailed nuclear shell-model studies by Zelevinsky and collaborators [2,3] established the importance of these measures. It also became clear that the Gaussian orthogonal ensemble (GOE) of random matrices is totally inadequate to explain the strong energy dependence of these quantities.

On the other hand the study of statistical spectroscopy in nuclei long ago [4–9] developed the embedded Gaussian orthogonal ensemble (EGOE), and in the last few years it has been realized that this ensemble is well suited for the study of chaos in quantum mechanical many-particle systems. Kota and Sahu [10] derived expressions for the information entropy and the number of principal components for EGOE and made numerical tests for their goodness [11].

The predictions of EGOE for strength sums of nuclear excitation operators and their agreement with the results from shell-model calculations in large $2p1f$ and $2s1d–2p1f$ spaces has been looked into recently