Giant Resonances using the UCOM and Second RPA*

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We aim to describe nuclear collective excitations starting from correlated realistic nucleon-nucleon (NN) interactions. The latter are constructed within the Unitary Correlation Operator Method (UCOM) [1, 2], which explicitly considers short-range correlations in order to properly soften the short-range behaviour of realistic NN potentials. It has been concluded that first-order RPA with a two-body UCOM interaction (UCOM-RPA) is not capable, in general, of reproducing quantitatively the properties of giant resonances (GRs), due to missing higher-order configurations and long-range correlations as well as neglected three-body terms in the Hamiltonian [3, 4]. In this work we go beyond first-order RPA and employ a UCOM interaction, V_{UCOM}, in Second RPA (SRPA) [5, 6]. The coupling between ph and $2p2h$ excitations is taken into account. Excitations are built on top of the Hartree-Fock (HF) ground state, as in the usual RPA. The same interaction is used to describe the Hartree-Fock (HF) ground state and the residual interactions. The HF-based formulation of SRPA preserves the sum rules m_0 and m_1 of RPA [5], but not symmetries like translational invariance [7].

We have used the correlated Argonne V18 interaction and we have examined the IS monopole (ISM), IV dipole (IVD) and IS quadrupole (ISQ) response of the nuclei ^{16}O and ^{40}Ca. We present our results in comparison with experimental data in Fig.1. In all cases, the SRPA centroid energies are much lower than the RPA ones. The reason is to a large extent that, within SRPA, the coupling of single-particle states with virtual phonons is implicitly taken into account. This dresses the underlying HF single-particle states with self-energy insertions and brings them closer to each other energetically, thereby lowering the underlying ph energies. It is an important physical effect which cannot be ignored when using completely "undressed" (with respect to long-range correlations) HF states like the ones produced by the V_{UCOM}. In this scheme the undressed HF energies are viewed as auxiliary model quantities which should not be directly compared with experiment.

We observe that the IV GDR is more realistically reproduced within SRPA than within RPA. Its centroid energy is somewhat underestimated. In the case of the IS GQR, the agreement of the SRPA results with experiment is very good. It appears as though, once coupling to higher-order configurations is taken into account, a realistic effective mass is restored. The energy of the IS GMR is underestimated. This is another indication that there are missing three-body effects and our two-body interaction should be supplemented with a three-body term to describe them.

In short, the UCOM-SRPA emerges as a promising tool for consistent calculations of collective states in closed-shell nuclei. This is an interesting development, given that SRPA can accommodate more physics than RPA (e.g., fragmentation) and provides a more fundamental treatment of the nucleon effective mass. Remaining discrepancies due to the missing three-body terms and self-consistency issues of the present SRPA model should be considered in future work. Up to now we have considered mostly the centroids of GRs, but their decay properties can also be studied within UCOM-SRPA. Heavier nuclei and low-lying states will be a topic for future work as well.

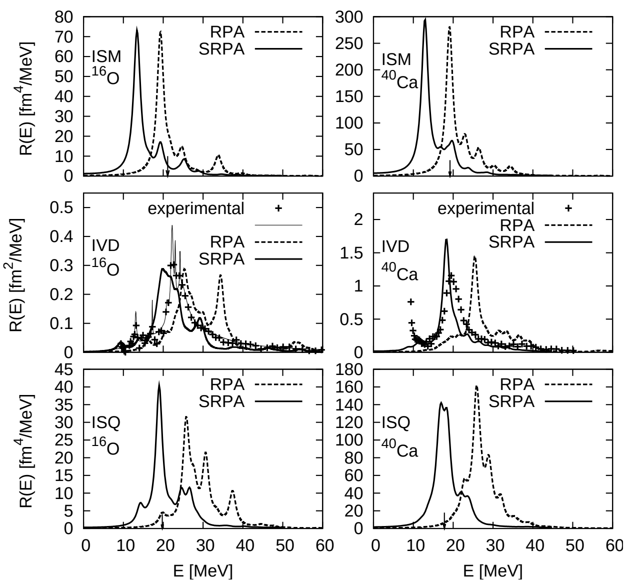

Figure 1: The ISM, IVD, and ISQ strength distributions for ^{16}O and ^{40}Ca compared with experimental data (points) or centroids (arrows) taken from Refs. [8, 9, 10, 11, 12].

* Supported by the Deutsche Forschungsgemeinschaft, SFB 634.

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