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Frontiers in Ab-Initio Computations of Atomic Nuclei

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Atomic nuclei exhibit multiple energy scales ranging from hundreds of MeV in binding energies to fractions of an MeV for low-lying collective excitations. Describing these different energy scales within an ab-initio framework is a long-standing challenge that we overcome by using high-performance computing, many-body methods with polynomial scaling, and ideas from effective-field-theory. With the recent advancements of ab-initio methods we can now address how collectivity and shape coexistence emerge in nuclei from chiral interactions. We accurately describe the first 2+ and 4+ energies and the quadrupole transitions from the first 2+ to the ground-state in neon isotopes. For 32,34Ne less is known and we predict that they are strongly deformed and collective. For 30Ne we interestingly find that a deformed and nearly spherical shape coexist, similar to what is seen in 32Mg. We also confirm that 78Ni has a low-lying rotational band, and that deformed ground states and shape coexistence emerge along the magic neutron number N = 50 towards the key nucleus 70Ca. On the neutron-deficient side we also addressed structure of nuclei around the strongly deformed N = Z = 40 nucleus 80Zr, although there are challenges our results are competitive with mean-field calculations. We also made predictions for the magnetic dipole transition in 48Ca. Here we found that the transition strength is consistent with a (γ,n) experiment but is larger than the results from inelastic electron- and proton-scattering experiments. With this talk I hope to convey that the accurate computation of multiscale nuclear physics demonstrates the predictive power of modern ab initio methods.

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