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Exploring the emergence of nuclear collectivity through moments and monopoles

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The emergence of collectivity in atomic nuclei is a primary research theme of the Australian National University Nuclear Structure Group. Through precision spectroscopy we aim to map emerging collectivity as valence nucleons are added to a doubly magic core, to elucidate the nature of weakly-collective nuclei, and to quantify the role of intruder configurations and shape-coexistence in weakly-collective nuclei.

Weakly collective nuclei are defined here as those that occur between nuclides that have a few valence nucleons outside a doubly magic core and those with many valence nucleons that show clear rotational bands. Highlights of recent research will be presented, with a focus on insights gained by confronting model calculations with experimental data on electromagnetic decays and moments [1-6].

There is increasing evidence that collectivity in nuclei emerges immediately as deformation and rotation, not vibration, and that the weakly deformed shapes tend to be triaxial. However, this evidence requires further investigation. The magnetic moments of weakly collective nuclei suggest that there is a class of nuclei, exemplified by the Te [2] and Xe [7] isotopes near 132Sn, that could be described as pre-collective, in that they begin to show collectivity in the low-excitation structure, but single-particle (seniority) structures also persist. Collectivity is emerging, but states that are 'more collective' exist along with states that are 'less collective'. Moreover, recent magnetic moment measurements on the Sn isotopic chain suggest emerging collectivity near N=60 that can be classified neither as vibration nor rotation [6]. In relation to models, important physics may be hidden by the use of effective charges [1,4,6].

The above discussion applies to heavier nuclei, where the nearest doubly magic nuclides have N > Z. Shape coexistence in doubly magic shell-model cores with N = Z, namely the existence of relatively low-excitation deformed multiparticle-multihole states, has long been known. However, measured electric monopole transition strengths are only now determining the degree of shape mixing, with increasing evidence that these presumed inert, spherical shell-model cores are in fact deformed in their ground states [5]. We are striving toward more complete spectroscopy of such nuclei and their neighbours to map emerging collectivity, by measuring E0 transition strengths and magnetic moments, along with E2 transition strengths.

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