NUCLEAR ASPECTS OF CONDENSED-MATTER NANOSYSTEMS

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The physics of condensed-matter nanosystems exhibits remarkable analogies with atomic nuclei. Examples are: Plasmons corresponding to Giant resonances [1], electronic shells, deformed shapes, and fission [2], beta-type decay, strongly correlated phenomena associated with symmetry breaking and symmetry restoration [3], etc.

The talk will review these analogies focusing in particular on the following two aspects:

(1) The shell-correction method (SCM, commonly known as Strutinsky's averaging method and introduced in the 1960's in nuclear physics) was recently formulated [4] in the context of density functional theory (DFT).

Applications of the DFT-SCM (and of a semiempirical variant, SE-SCM, closer to the nuclear Strutinsky approach) to condensed-matter finite systems will be discussed, including metal clusters, fullerenes, and metallic nanowires [4]. The DFT-SCM offers an improvement compared to the use of Thomas-Fermi gradient expansions for the kinetic energy density functional in the framework of orbital-free DFT.

(2) A unified description of strongly correlated phenomena in finite systems of repelling particles (whether electrons in quantum dots or ultracold bosons in rotating traps) has been achieved through a two-step method of symmetry breaking at the unrestricted Hartree-Fock (UHF) level and of subsequent symmetry restoration via post Hartree-Fock projection techniques [3]. The general principles of the two-step method can be traced to nuclear theory (Peierls and Yoccoz) and quantum chemistry (Löwdin).

This method can describe a wide variety of novel strongly correlated phenomena, including:

(I) Chemical bonding, dissociation, and formation of Heisenberg spin clusters in quantum dot molecules and in single elliptic QDs, with potential technological applications to solid-state quantum computing.

(II) Particle localization at the vertices of concentric polygonal rings and formation of rotating (and other less symmetric) Wigner molecules in quantum dots and ultracold rotating bosonic clouds.

(III) At high magnetic field (electrons) or rapid rotation (neutral bosons), the method yields analytic trial wave functions in the lowest Landau level [5], which are an alternative to the fractional-quantum-Hall-effect (FQHE) composite-fermion and Jastrow-Laughlin approaches.

Other applications concern: (a) symmetry-conserving rotating vortex clusters beyond the broken-symmetry Gross-Pitaevskii vortex solutions [6]; (b) FQHE analogies and differences in finite graphene samples [7].

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