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Shell model: recent advances from mid-mass to superheavy elements

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In this presentation, I will expose some of the latest developments in microscopic nuclear structure calculations from mid-mass to superheavy elements. In a first part, I will present developments and applications for the diagonalisation of shell-model hamiltonians in a Discrete Non-Orthogonal Shell Model (DNO-SM)[1] and its latest implementation DNO-SM(VAP)[2]. The method is based on mean-field and beyond-mean field techniques with focus on basis states optimization within a double variation after projection approach. Numerical applications are benchmarked and illustrated against Large Scale Shell Model diagonalisations.
In a second part, this new development will be used to address the subject of high collectivity along the N=Z line. In particular, heavy N=Z nuclei in the mass region A=80 are expected to be some of the most deformed ground states which have been found[3] in mid-mass nuclei, typically 8p-8h,12p-12h for e.g. the cases of 76Sr, 80Zr and more recently extended to 84Mo and 86Mo. This strong enhancement of collectivity with respect to lighter N=Z nuclei has its origin in cross shell excitations across the N=40 shell gap to g9/2, d5/2 and s1/2 which are intruder quadrupole partners generating deformations. I will interpret these structures in terms of the simple Nilsson-SU3 algebraic model[4]. New theoretical calculations for the very region of 80Zr will be presented within the interacting shell model framework from both exact Shell Model diagonalisations and DNO-SM(VAP) approaches[5]. This whole region of collectivity is identified as a new Island of Inversion at the N=Z line.

The DNO-SM(VAP) approach also allows to study superheavy systems within the Shell Model framework and I will present and discuss the first complete description of low-lying spectroscopy in 254No[2].

Finally I will discuss the new perspectives opened with these recent advances.

[1] D. D. Dao and F. Nowacki, Phys. Rev. C 105, 054314 (2022),
[2] D. D. Dao and F. Nowacki, arXiv:2409.08210
[3] R. D. O. Llewellyn et al., Phys. Rev. Lett. 124, 152501 (2020).
[4] A. P. Zuker et al., Phys. Rev. C 92, 024320 (2015)
[5] D. D. Dao, F. Nowacki, A. Poves in preparation

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