In this talk, I will discuss challenges of a large-scale modeling of atomic nuclei and will introduce a novel method, the symmetry-adapted no-core shell model. This approach unveils the emergence of orderly patterns that favor spatial configurations with strong quadrupole deformation and complementary low intrinsic spin values. Such a feature is consistent with the symplectic model of the nuclear collective motion and can be used to expand the reach and predictive power of first-principle studies.