Living at the edge of stability, understanding the limits of the nuclear landscape: Computational and algorithmic challenges.

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To understand why matter is stable, and thereby shed light on the limits of nuclear stability, is one of the overarching aims and intellectual challenges of basic research in nuclear physics. To relate the stability of matter to the underlying fundamental forces and particles of nature as manifested in nuclear matter, is central to present and planned rare isotope facilities. Important properties of nuclear systems, which can reveal information about these topics are for example masses, and thereby binding energies, and density distributions of nuclei. These are quantities, which convey important information on the shell structure of nuclei, with their pertinent magic numbers and shell closures or the eventual disappearance of the latter away from the valley of stability. Neutron-rich nuclei are particularly interesting for the above endeavor. As a particular chain of isotopes becomes more and more neutron rich, one reaches finally the limit of stability, the so-called dripline, where one additional neutron makes the next isotopes unstable with respect to the previous ones. The appearance or not of magic numbers and shell structures, the formation of neutron skins and halos can thence be probed via investigations of quantities like the binding energy or the charge radii and neutron rms radii of neutron-rich nuclei. In this talk I will present some recent calculations on properties of oxygen, calcium and nickel isotopes towards their corresponding driplines and point to new experiments. In particular I will focus on ground state properties and excited states, with an emphasis on the role of two- and three-body forces using first principles methods like large scale diagonalization approaches, coupled-cluster theory, in-medium Similarity Renormalization group and diffusion Monte Carlo. I will also try to outline present and futurechallenges to nuclear many-body theory and how to understand the above properties in terms of the underlying forces. The computational challenges will be outlined as well, with an emphasis on various methods together with additional applications to systems from solid state physics like quantum dots and infinite homogeneous matter like neutron star matter or the electron gas in two and three dimensions.