Solving Nuclear Structure Problems with a Variational Quantum Algorithm

Antonio Márquez Romero[1,2]

J. Engel[2], Ho Lun Tang[3], Sophia E. Economou[3]

[1] Department de Fisica Quantica i Astrofisica, Institut de Ciencies del Cosmos (ICCUB), Universitat de Barcelona, Marti i Franques 1, Barcelona, E08028, Spain

[2] Department of Physics and Astronomy, University of North Carolina, Chapel Hill, North Carolina 27516-3255, USA

[3] Department of Physics, Virginia Tech, Blacksburg, VA 24061, USA

a.marquez.romero@fqa.ub.edu

We use the Lipkin-Meshkov-Glick (LMG) model and the valence-space nuclear shell model to examine the likely performance of variational quantum eigensolvers in nuclear-structure theory. The LMG model exhibits both a phase transition and spontaneous symmetry breaking at the mean-field level in one of the phases, features that characterize collective dynamics in medium-mass and heavy nuclei. We show that with appropriate modifications, the ADAPT-VQE algorithm [1], a particularly flexible and accurate variational approach, is not troubled by these complications. We treat up to 12 particles and show that the number of quantum operations needed to approach the ground-state energy scales linearly with the number of particles [2]. We find similar scaling when the algorithm is applied to the nuclear shell model with realistic interactions in the sd and pf shells.

References

[1] H.R. Grimsley, Sophia E. Economou, E. Barnes et al, Nature Communications 10, 3007 (2019)

[2] A. M. Romero, J. Engel, Ho Lun Tang, Sophia E. Economou, arXiv:2203.01619 (2022)

Figures

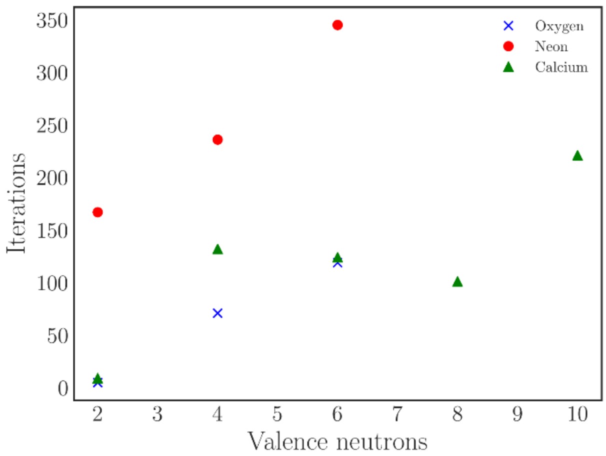

Figure 1: Number of operations needed to reach the ground-state energy of the nucleus to within 1%, 2% and 0.0001% for isotopes of calcium, neon and oxygen, respectively, as a function of the number of valence neutrons in the shell.