Coupled Cluster Approach to Medium Mass and Neutron Rich Nuclei.

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The nuclear many-body problem is a challenging undertaking, and coupled-cluster theory is a very promising candidate for pushing the *ab initio* nuclear structure program into regions of medium mass and neutron rich nuclei. With coupled-cluster theory, it is our goal to address the two frontiers in the nuclear physics community; *What is the role of three-nucleon forces in medium mass and neutron rich nuclei? What is the role of the scattering continuum on the evolution of nuclear shell structure and location of driplines?*

Recently we reformulated coupled-cluster theory in a spherical formulation, and this allowed us to treat model space sizes of 20, or more, major oscillator shells. With these enormous model space sizes we could study the saturation of ``bare" chiral NN interactions in medium mass nuclei [1,2] and in the neutron rich oxygen isotopes ^{16,22,24,28}O [3]. In particular, we found that ^{16}O and ^{48}Ca are under bound by about 400keV per particle while ^{40}Ca is slightly over bound with respect to experiment.

We have also developed spherical equation-of-motion theory for the description of ground- and excited states in the odd mass A ± 1 neighbours of a closed shell nucleus with mass A. With the spherical formulation we can handle the enormous model space sizes required to take the coupling with the scattering continuum into account. In Ref. [5] we presented the first *ab initio* calculation of the $1/2^+$ halo state in ^{17}F and the $3/2^+$ resonances in ^{17}F and ^{17}O using equation-of-motion coupled-cluster theory and chiral NN interactions. We found that the coupling with the continuum gives a significant amount of additional binding for the low-lying $1/2^+$, $3/2^+$, and $5/2^+$ states in ^{17}F and ^{17}O. Our calculation of the $1/2^+$ state in ^{17}F agree remarkably well with experiment, and we argue that this state is insensitive to short ranged three-nucleon forces. The calculated energies of the $3/2^+$ resonances in ^{17}F and ^{17}O are in rather good agreement with experiment, but the ($3/2^+$ - $5/2^+$) spin-orbit splitting are too compressed due to the lack of three-nucleon forces.

[1] G. Hagen, T. Papenbrock, D. J. Dean, and M. Hjorth-Jensen, Phys. Rev. Lett. **101,** 092502 (2008).
[2] G. Hagen, T. Papenbrock, D. J. Dean, M. Hjorth-Jensen, submitted to Phys. Rev. C (2010), arXiv:1005.2627.
[3] G. Hagen, T. Papenbrock, D. J. Dean, M. Hjorth-Jensen, and B. Velamur Asokan, Phys. Rev. C **80**, 021306 (2009).
[4] G. Hagen, T. Papenbrock, and D. J. Dean, Phys. Rev. Lett. **103**, 062503 (2009).
[5] G. Hagen, T. Papenbrock, and M. Hjorth-Jensen, Phys. Rev. Lett. **104**, 182501 (2010).