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Tom W. Bonner Prize in Nuclear Physics Talk: Finding Real Nuclei in Imaginary Time[1]

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Ab initio calculations of nuclei treat a nucleus as a system of A nucleons interacting by realistic two- (NN) and three-nucleon (NNN) forces. Variational Monte Carlo (VMC) followed by Green's function Monte Carlo (GFMC) is a very successful ab initio method for light nuclei. The VMC gives an upper bound to the true energy of a nucleus for a given Hamiltonian; the closeness of the upper bound to the exact solution of the Schrödinger equation depends on the physical insight built into the trial wave function, Ψ_T, that is used. GFMC starts with a Ψ_T and, by propagation in imaginary time, allows the exact lowest eigenenergy for a given set of quantum numbers to be computed. The first VMC calculations of nuclei were published in 1981 by Lomnitz-Adler, Pandharipande, and Smith. They were for ^{3}H and ^{4}He using the Reid NN potential. Six years later, Carlson published the first GFMC calculations of nuclei, again for ^{3}H and ^{4}He, but using a slightly-simplified NN potential; in the following year he used the full Reid V8 potential. Pudliner, Pandharipande, Carlson, and Wiringa published GFMC calculations of A=6 nuclei in 1995, using the Argonne V18 NN potential and the Urbana IX NNN potential. Since then there has been steady progress in applying GFMC to larger nuclei. This has been from both increasing computer power and new or improved algorithms. The largest computers are increasingly difficult to use efficiently, but, as a result of a SciDAC collaboration, we now get excellent scalability up to 131,000 cores on Argonne's IBM Blue Gene/P. In addition we have found that the GFMC can be used for multiple states with the same quantum numbers. With the Argonne V18 and Illinois NNN potentials, we obtain an excellent description of the properties of nuclei up to $A = 12$. I will describe these methods, present recent advances in using the largest computers, and some recent results.

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