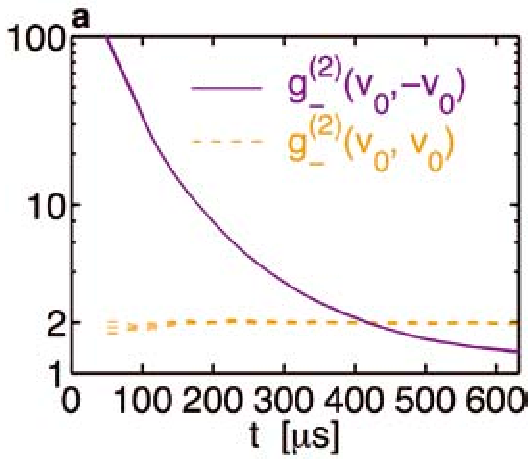
# Quantum dynamics in many-body systems

J. Hedditch, J. F. Corney, T. G. Vaughan, S. Hoffmann, D. Barry and P. D. Drummond
*ACQAO, School of Physical Sciences, University of Queensland, Australia*

Techniques for quantum simulations were developed further and applied to very large systems in 2007, including a hybrid approach suitable for quantum Brownian motion, and novel techniques for spin systems. The Gaussian phase-space method developed at ACQAO[1, 2, 3], was recently highlighted by a Japanese computational physics team[4] in a paper on the relevance of the well-known Hubbard model for high-Tc superconductivity. Using the method, they were able to explore previously intractable regions of the strongly interacting Hubbard model with any approximation or sign-error.

**BEC collision with 150,000 atoms from first principles**

The collision of pure $^{23}$Na BECs, as in a recent experiment at MIT, represents a superb opportunity for observational tests of first-principles quantum dynamical simulations. In these simulations[5], a $1.5 \times 10^6$ atom BEC is divided into two halves with opposite velocities, which then collide freely. The dynamics of the correlations between the scattered atoms are shown below:




The figure to the left shows the extremely strong quantum correlations predicted between atoms with opposite velocity (solid line), and thermal correlations between scattered atoms at the same velocity (dashed). **This is the first exact quantum dynamical simulation of colliding BECs.** Measurable results similar to that predicted by this model have been seen experimentally. Our model treats $2^{600,000}$ quantum states, or $600,000$ qubits. The resulting paper was published in Physical Review Letters in 2007[5], and awarded a rare **Editor's suggestion.**

**XMS simulation code**

XMDS, a novel code generator program, is used for quantum dynamical simulations. An extensive rewriting of this program was carried out, with a view to creating a much shorter, easily modified and more efficient code generator, with a modular library for different applications, easily modified by end-users. To deal with end-user requirements, development was extended to a code-generator with a much simpler yet more powerful simuation language, called XMS. The new code-generator is written in the high-level Python language. Although any output computer language is possible, the initial development has focused on the powerful FORTRAN 90 language, due to its extensive array-handling ability. This was successfully implemented, and is now in the testing and documentation phase.

## References

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