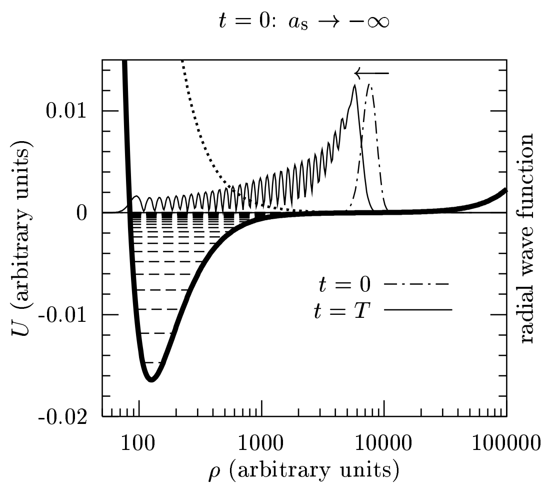
# Many-body Efimov states in boson condensates

O. Sørensen, D. V. Fedorov, and A. S. Jensen
Institute of Physics and Astronomy, Univ. of Aarhus, 8000 Århus C, Denmark

The method developed for weakly bound halos is extended to study two-body correlations within a system of $N$ identical bosons. The structure and decay of Bose condensates depend strongly on two-body correlations between the bosons. The new formulation [1] uses hyperspherical coordinates and adiabatic expansion with a Faddeev type of decomposition of the wave function where all pairs of particles are treated equally. First the angular equation is solved and then the one-dimensional effective potential $U$ depending on hyperradius $\rho$ is constructed. Large scattering lengths can be treated in contrast to virtually all other methods. Furthermore it is possible to compute the dominating decay rate of the condensate, i.e. three-body recombination into bound dimers [2].

We discuss the structure of trapped boson systems as a function of scattering length $a_s$ for attractive finite range potentials, and obtain a criterium for stability: $N|a_s|/b_t < 0.6$, where $b_t$ is the trap length. We focus on a new multi-particle Efimov effect at large scattering length, where infinitely many loosely bound many-body states appear. A confining external trap however only allows a finite number, $N_E$, of such spatially extended negative energy states inside the trap, see figure. We obtain $N_E \approx 0.5N \ln(b_t/(37b))$, where $b$ is the interaction range.




Effective potential $U(\rho)$ for $N = 20$ and zero (dotted curve) and infinite (thick, solid curve) scattering length. Also shown is the lowest radial wave function for zero scattering length (dot-dashed curve). The thin, solid curve shows the radial wave function after half a period of a cycle of contraction and expansion, which sets in after a sudden change from zero to infinite scattering length. Energy levels for infinite scattering length are shown as dashed, horizontal lines.

An especially dramatic collapse of the condensate could be initiated experimentally [3] by first creating a non-interacting condensate (potential of the dotted curve), followed by a sudden, large increase in magnitude of the scattering length (thick, solid curve). The initial state (dot-dashed curve) would then contract (thin, solid curve) and expand in a periodic cycle. The multi-particle Efimov states would then quickly be populated, and these states would subsequently leak out of the trap due to recombination. We suggest this new mechanism for decay through these intermediate states of extensions between the interaction range and the size of the condensate.

[1] O. Sørensen *et al.*, cond-mat/0110069, PRA in press; cond-mat/0203400.
[2] E. Nielsen and J. H. Macek, Phys. Rev. Lett. **83**, 1566 (1999).
[3] E. A. Donley *et al.*, Nature **412**, 295 (2001).