Solitons as the Early Stage of Quasicondensate Formation during Evaporative Cooling

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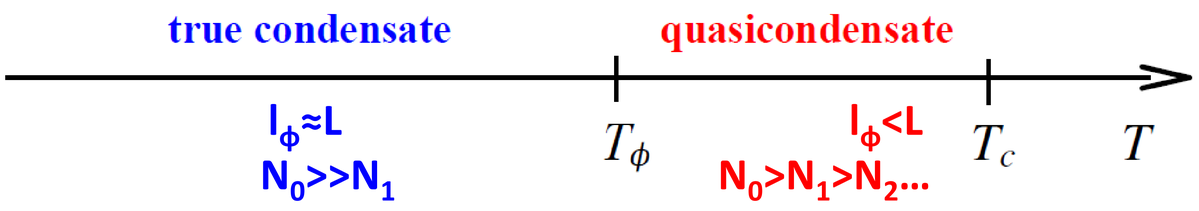
Abstract: We calculate the evaporative cooling dynamics of trapped 1D Bose-Einstein condensates for parameters leading to a range of condensates and quasicondensates in the final equilibrium state, using the classical fields method. We confirm that solitons are created during the evaporation process by the Kibble-Zurek mechanism, but subsequently dissipate during thermalisation. However, their signature remains in the phase coherence length, which is approximately conserved during dissipation in this system.

1D Bose Gas in a Trap

At thermal equilibrium: for weakly interacting gas there are two characteristic temperatures

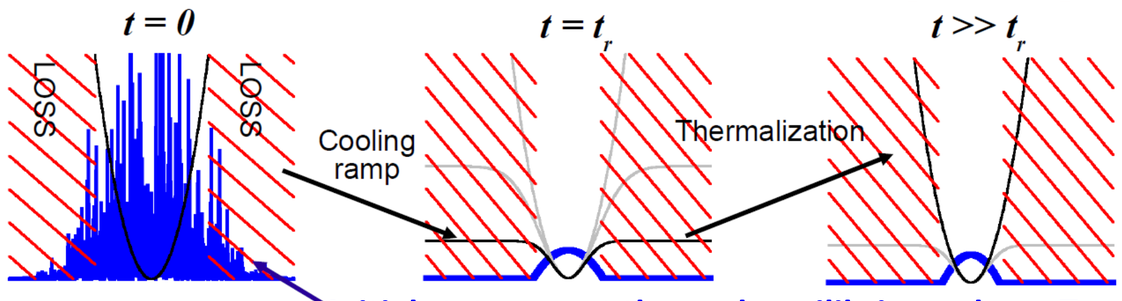


Out of equilubrium dynamics: spontaneous solitons formation via Kibble-Zurek mechanism

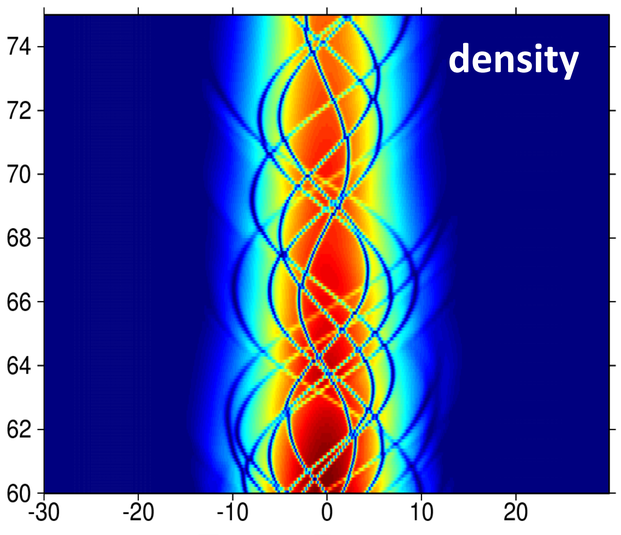
The Model

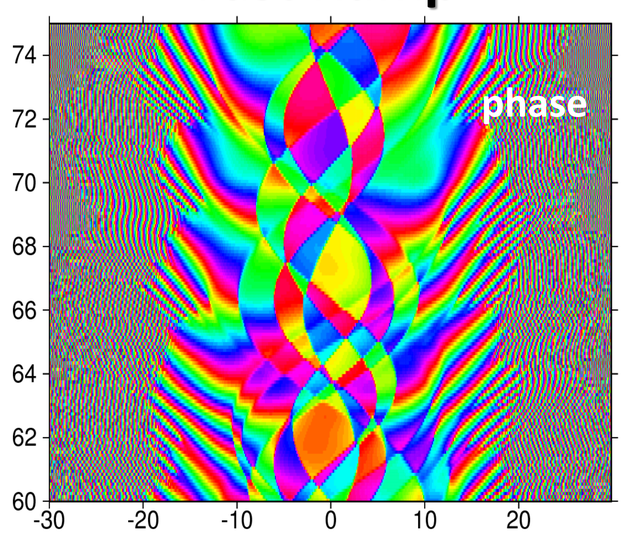
$$i\hbar\partial_t\psi(z,t) = (-\frac{\hbar^2}{2m}\Delta + g_{1D}|\psi(z,t)|^2 + H_{ev}(z,t) - i\Gamma(z,t))\psi(z,t)$$

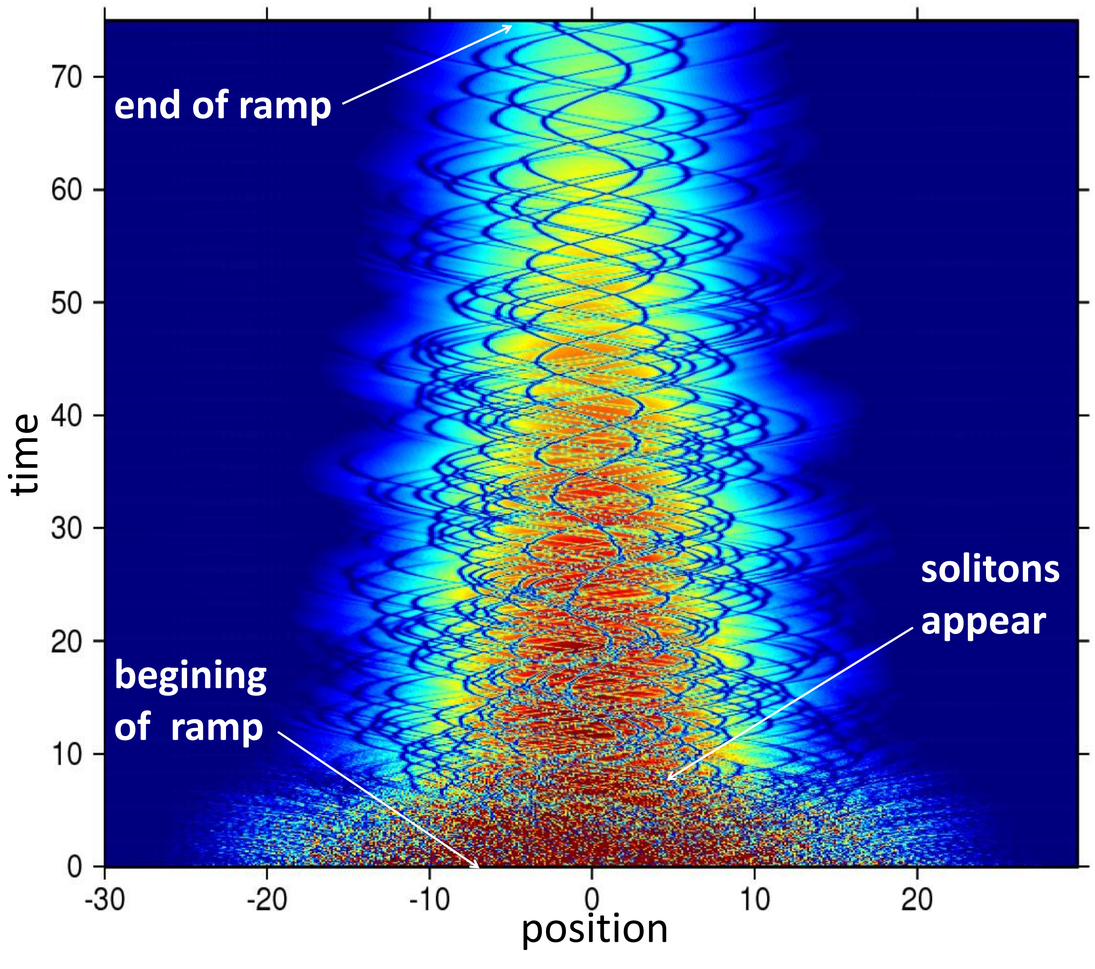
$$H_{ev}(z,t) = U(t)\left[1 - e^{-\frac{1}{2}\left(\frac{z}{s_z}\right)^2 \frac{U_0}{U(t)}}\right] \qquad \Gamma(z,t) = \Gamma_\infty\left[\frac{H_{ev}(z,t)}{U(t)}\right]^\gamma$$

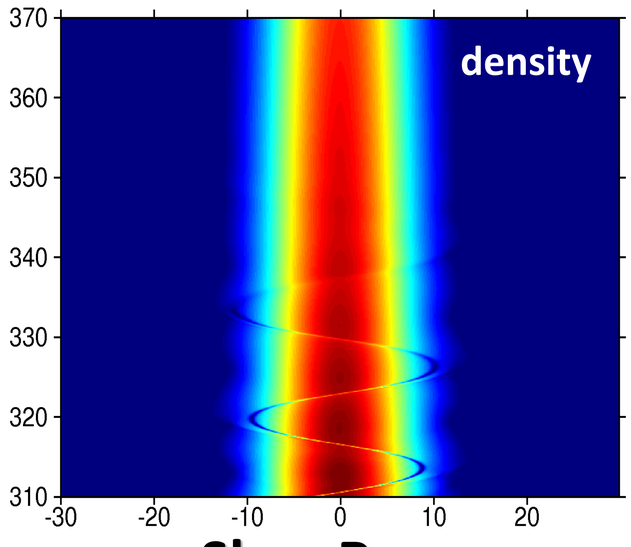


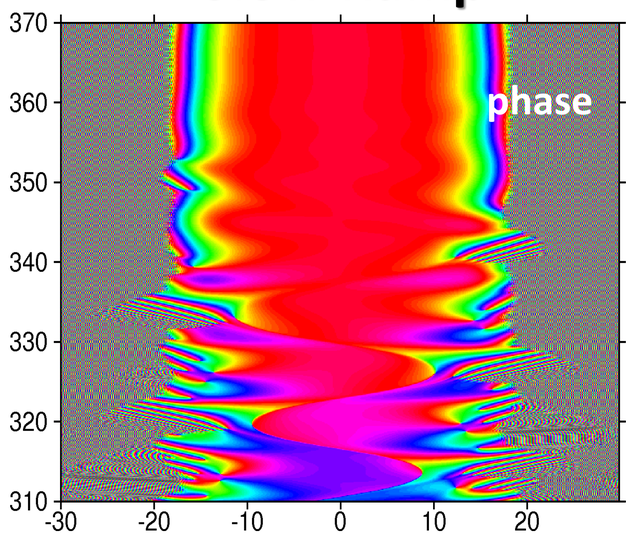
Evaporative Cooling Dynamics



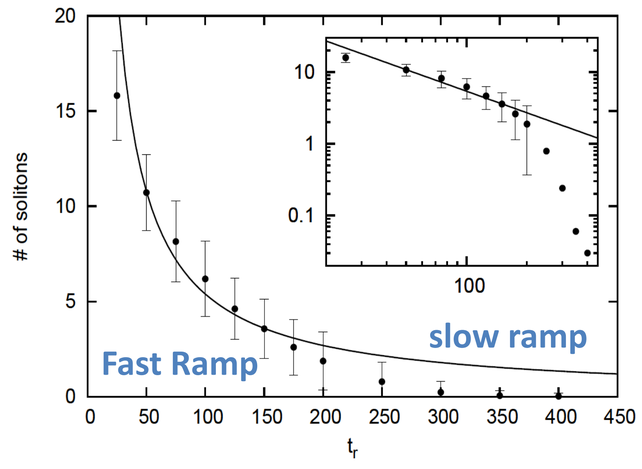


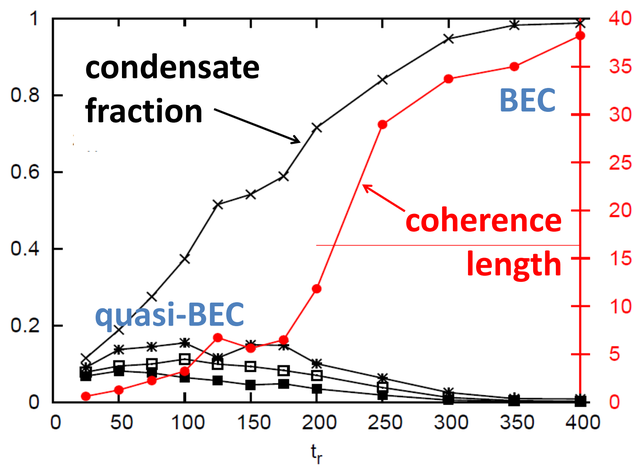




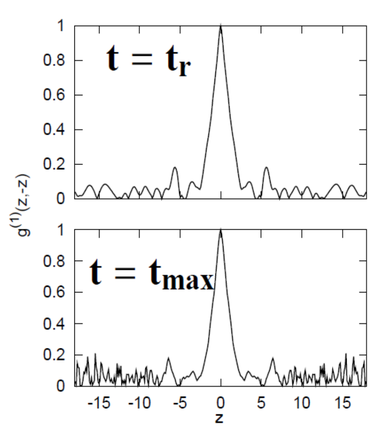


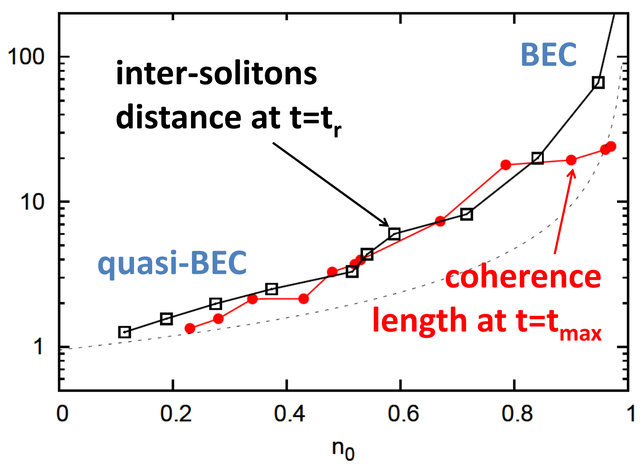
At the End of the Ramp





Solitons vs Quasicondensate





In conclusion:
the match between inter-soliton distance at the end of the ramp and phase coherence length at long times shows that the equlibrium phase fluctuations of quasicondensates are the transformed remnant of the solitons formed by the KZM in this scheme of evaporative cooling.

References:

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- W.H. Zurek, Phys. Rev. Lett. **102**, 105702 (2009);
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