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**Quantum Shock waves and Population Inversion in Collisions of Ultracold Atomic Clouds**[1] SEBASTIANO PEOTTA, MASSIMILIANO DI VENTRA, Univ of California - San Diego — Using Time-Dependent Density Matrix Renormalization Group (TDMRG) we study the collision of one-dimensional atomic clouds confined in a harmonic trap and evolving with the Lieb-Liniger Hamiltonian [1]. It is observed that the motion is essentially periodic with the clouds bouncing elastically in agreement with the results of the "quantum Newton cradle" experiment of Kinoshita et al. [Nature 440, 900 (2006)]. We compare the results for the density profile against a hydrodynamic description with the pressure term taken from the Bethe Ansatz solution of the Lieb-Liniger model. We find that hydrodynamics can describe the breathing mode of a harmonically trapped cloud for arbitrary long times while it breaks down almost immediately for the collision of two clouds due to the formation of shock waves (gradient catastrophe). Concomitantly with the shock waves formation we observe a local energy distribution typical of population inversion, i.e., an effective negative temperature. Our results are an important step towards understanding the hydrodynamics of quantum many-body systems out of equilibrium and the role of integrability in their dynamics.

[1] S.. Peotta and M. Di Ventra, arXiv:1303.6916

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