Towards simulation of impurity movement through a Tonks-Girardeau gas

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Abstract

Recent advances in the field of atom cooling and trapping have led to renewed interest in low dimensional quantum systems [1]. In particular, the case of a strongly interacting Bose gas (in the so called Tonks-Girardeau regime) has attracted considerable interest [2, 3].

In a recent experimental paper [4], the movement of a spin impurity through a quasi one-dimensional Tonks-Girardeau gas has been investigated. Impurity atoms are produced by coupling a fraction of the tube of Tonks-Girardeau atoms into an untrapped hyperfine level. This impurity is accelerated through the trapped cloud by gravity. Interesting results have been observed, indicating complex dynamics between the in-trap component and impurity atoms.

In this work, the theoretical treatment of Tonks-Girardeau gases is simplified by the Fermi-Bose mapping theorem [2], which allows local density and correlation functions of strongly interacting Bose gases to be related directly to those of free fermions.

Preliminary results are presented, outlining the centre of mass motion of the impurity atoms and density profiles for both components. Results show good qualitative agreement with experimental data, though the large density fluctuations seen in the experiment have so far not been observed 'upstream'. Figure 1 shows density profiles for the impurity atoms (red) and the in-trap component (blue) before and after acceleration by gravity. Current work and planned refinements to the simulation are also presented.

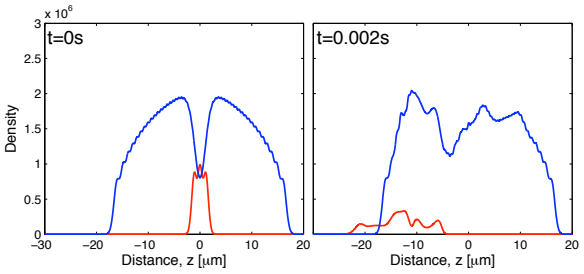

Figure 1: (left) Initial density profiles for impurity atoms (red) and in-trap component (blue) for a sample of 50 Rb atoms.
(right) Density profiles after 0.002s. Impurity atoms have been accelerated downwards by gravity, experiencing significant dissipation due to strong interactions with the trapped cloud (trap frequency $\omega_z = 2\pi \times 39$ Hz).

Keywords: TONKS, TONKS-GIRARDEAU, IMPURITY, QUANTUM TRANSPORT

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