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One-dimensional Quantum Fluids

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Fifty year ago, Joachim Mazdak Luttinger generalized the Tomonaga theory of interactions in a one-dimensional metal and show that the prior restrictions imposed by Tomonaga were not necessary. This model is now known as the Tomonaga-Luttinger liquid model (TLL) and most remarkably it does have mathematically exact solutions. In the case of electrons, it predicts that the spin and charge sector should separate, with each of them propagating with their own velocities. While there has been many attempts (some with great success) to observe TLL behaviour in clean quantum wires designed on an ultra-clean semiconductor platform, overall the Luttinger physics is experimentally still in its infancy. For instance, little is known regarding the 1D physics in a strongly-interacting neutral system, whether from the point-of-view of TLL theory or even localization physics. Helium-4, the paradigm superfluid, and Helium-3, the paradigm Fermi liquid, should *in principle* both become Luttinger liquids if taken to the one-dimensional limit. In the bosonic case, this is supported by large-scale Quantum Monte Carlo simulations [1] which found that a lengthscale of ~ 2 nm is sufficient for the system to crossover to the 1D regime and display universal Luttinger scaling [2]. At McGill University, an experiment has been constructed to measure the liquid helium mass flow through a *single nanopore*. The technique consists of drilling a single nanopore in a SiN membrane using a TEM, and then applying a pressure gradient across the membrane. Previously published data in 45nm diameter hole determined the superfluid critical velocity to be close to the limit set by the Feynman vortex rings model [3]. More recent work performed on nanopores with radii as small as 3 nm (and a length of 30nm) show the critical exponent for superfluid velocity to significantly deviate from its bulk value, 2/3. This is an important hint for the crossing over to the one-dimensional state in a strongly-correlated bosonic liquid. References_[1] Del Maestro A, Boninsegni M, Affleck I. ^{4}He Luttinger Liquid in Nanopores. *PHYSICAL REVIEW LETTERS 106*: 105303, 2011. [2] Kulchytskyy B, Gervais G, Del Maestro A. Local superfluidity at the nanoscale. *PHYSICAL REVIEW B 88*: 064512, 2013. [3] Savard M, Dauphinais G, Gervais G. Hydrodynamics of Superfluid Helium in a Single Nanohole. *PHYSICAL RE- VIEW LETTERS 107*: 254501, 2011.