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Luttinger liquid behavior in a one-dimensional conductor

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In two- and three-dimensional metals, electrons near the Fermi level are scattered around defects or impurities and the interacting electrons are well described by the Fermi liquid theory of non-interacting quasi-particles. In one-dimensional (1D) metals, standing waves of the screening electrons near the Fermi level can also be produced around defects. However, even weak electron-electron interaction can destroy the picture of non-interacting quasi-particles. These correlated 1D electrons are better described by the Luttinger liquid theory. Electronic standing waves with two different wavelengths were directly mapped near one end of a single-wall carbon nanotube (SWNT) as a function of the tip position and the sample bias voltage with high-resolution position-resolved scanning tunneling spectroscopy (PR-STS). The observed standing waves and their super-modulations caused by spin and charge bosonic excitations are found to constitute direct evidence for a Luttinger liquid. The increased group velocity of the charge excitation, the power-law decay of their amplitudes away from the scattering boundary, and the suppression of the density of states near the Fermi level were also directly observed or calculated from the two different standing waves.