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Weak values and weak measurement in elementary scattering and reflectivity –a new effect

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Weak values (WV) and two-state-vector formalism (TSVF) [1] provide novel insights in quantum-information processing, quantum thermodynamics, nanoscale quantum systems, complex materials, etc.
In the theoretical part of the talk, we explore a new quantum effect of scattering accompanying an elementary collision of two quantum systems A and B, the latter interacting with a quantum environment. In clear contrast to a classical environment, the quantum case can exhibit new counter-intuitive features, e.g. momentum and/or energy transfer which contradict every conventional theoretical expectation.
As an example, the experimental part of the talk shows experimental evidence of a quantum deficit of momentum transfer and/or enhanced energy transfer (or, equivalently: reduced effective mass) in an elementary neutron-atom collision. The experimental method is incoherent inelastic neutron scattering (INS), available at neutron spallation sources (e.g., SNS, Oak Ridge Nat. Lab, USA). This INS-effect was recently observed [2] on single H2 molecules confined and physisorbed in (i.e., weakly interacting with) multi-walled carbon nanotube channels with diameter ˜10 Å. The INS results, if interpreted within conventional theory, reveal a strikingly reduced effective mass of the translation motion of the recoiling H2 molecule, i.e. M = 0.64 ± 0.07 amu (atomic mass units). This is in blatant contrast to that of a completely free recoiling H2 for which the mass must be 2 amu.
In contrast, the finding has a "first principles"qualitative interpretation within modern theory WV and TSVF [1, 3]. A qualitative quantum-mechanical interpretation (see [3]) can reveal new features of the considered experimental observation being in clear contrast to conventional neutron scattering theory. Moreover, analyzed in the WV-theoretical context, the experimental result demonstrates the following: (1) the scattered neutron is a quantum system; (2) the experiment determines (or: measures), for the first time, the overlap of the initial-state wavepacket with that of the final-state of the recoiling H2 (in momentum space).
The effect under consideration may have far-reaching consequences also in other fields (e.g. reflectivity, SANS, SAXS), and in relativistic scattering processes.

[1] Y Aharonov, D Rohrlich. Quantum Paradoxes: Quantum Theory for the Perplexed. (Weinheim, Wiley-VCH, 2005)
[2] R J Olsen et al., *Carbon* **58**, 46 (2013)
[3] C A Chatzidimitriou-Dreismann, *Quanta* **5**, 61 (2016)

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