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Quantum Diffractive Collision Universality and the Quantum Pascal

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Cold atoms have revolutionized experimental physics, leading to breakthroughs ranging from the creation of new states of quantum matter to the redefinition of the primary SI units. In our work, we have been studying collisions between cold Rb atoms held in a magnetic trap and room temperature background gas particles. These collisions are particularly interesting owing to the fact that they include long-range (high impact parameter and high angular momentum) interactions which impart very little momentum to the trapped atoms, so-called quantum diffractive (QD) collisions. Cold, trapped atoms have low momenta and large deBroglie wavelengths, making them excellent detectors for quantum diffractive collisions. The small momentum changes are measured through the loss rate of the "sensor"atoms from shallow magnetic traps, whose depths, U, can be varied. Namely, the variation of the loss rate with trap depth is a momentum spectrometer. In this talk, I will present our recent discovery of a new class of universality which describes the velocity-averaged loss rate coefficient associated with QD collisions,

$\langle\sigma_{\rm loss}v\rangle = \langle\sigma_{\rm tot}v\rangle\left[1-\sum_j\beta_j\left(\frac{U}{U_d}\right)^j\right]$.

Here, $\langle\sigma_{\rm tot}v\rangle$ is the velocity averaged total cross-section, $U_d = 4\pi\hbar^2 v_p/(m_t\langle\sigma_{\rm tot}v\rangle)$ is a characteristic energy scale for quantum diffractive collisions, m_t is the mass of the trapped atom, and v_p is the most probable speed for the room temperature background particle. The β_j coefficients are universal, characterising the nature of the QD collision interaction. That is, each form of long-range interaction, $-C_n/R^n$, are a different class of universality with unique β_j. This universality has been demonstrated for atom-atom (Rb-X, X = He, Ar, Xe) and atom-molecule (Rb-X, X = H_2, N_2, CO_2) collisions, characterized by a long range potential of the form $-C_6/R^6$. This breakthrough has allowed us to define the "quantum pascal", a definition of the Pascal based on the *measured* velocity average total collision cross-sections and on immutable atomic properties.

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