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New discoveries and observations of universal physics in collisions

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In physics, universality refers to the existence of properties that are independent of short-range structural details. For example, critical phenomena that are insensitive to the details of microscopic interactions exhibit the same bulk scaling behavior (e.g. critical exponents and scaling functions) for microscopically distinct systems. Such insensitivity of the low-energy degrees of freedom to small scale structures is key in the development of effective field theories, and universality arises in few-body physics when the scattering length is much larger than the interaction range. Universality is therefore a powerful and intuitive avenue for understanding and applying the physics of complex phenomena.

In this talk, we present an overview of recent work on two forms of universality in collision physics. We present experimental observations of the universal and non-universal decay rate of ultra-cold, reactive molecules, and we report the discovery of a new form of universality for collisions that occur at very large impact parameters and transfer exceedingly little kinetic energy. We find both theoretical and experimental evidence that these so-called quantum diffraction collisions are universal and that the energy transferred by them encodes information about the total collision cross section and the form of the interaction potential at long range. This universality phenomenon (which we refer to as QDU) is a manifestation of the Heisenberg uncertainty principle and a consequence of the collision induced particle localization. QDU therefore occurs for any interaction and applies to collisions of both elementary and composite particles (e.g. nuclei, atoms and molecules). Because of its fundamental nature and broad implications to collisions of all types, we believe this discovery is of general interest. Using QDU for van der Waals interactions, we realize a self-defining flux sensor using cold atoms providing the first primary and quantum definition of the Pascal applicable to any atomic or molecular species.

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