Fundamental study and practical applications of ion-atom collisions

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Recent work has continued the long historical trend in which achievements of theoretical and experimental study of ion-atom collisions has yielded both fundamental new physical insights and results that underpin practical applications. Examples of this include the new insights derived from the hydrodynamical interpretation of ion-atom collisions and the production of reliable and comprehensive data to model solar wind proton transport through the heliosphere and to model the ionosphere-atmosphere coupling at Jupiter.

The study of ion-atom collisions remains both a vital area of fundamental research yielding new physical insights as well as resulting in ever more detailed and complete knowledge required for applications in plasma science, astrophysics, and other areas of research and industry.

In fact, by the 1980's most of the theoretical tool kit needed to describe ion-atom collisions was in place, following the development over the previous six decades of perturbation theory, close coupling, and other methods of scattering theory, combined with fundamental discoveries and benchmarking measurements made through the parallel development of experiments.

The subsequent years then led to a fertile period of discovery and/or explanation of effects, such as the enhancement or oscillation of the binary peak, insights into correlation derived from study of the Thomas double scattering mechanism, so-called "two-center effects", etc., as well as to a period in which it was feasible to create large scale data sets of increasing reliability for applications.

An example of the continued uncovering of new insights is given by the recent renaissance of the hydrodynamical interpretation of quantum mechanics as applied to ion-atom collisions [1 and references therein]. Such results have been enabled by 3-dimensional solution of the time-dependent Schrödinger equation on large numerical grids using high-order representation of the derivative operators, first becoming practical in the late 1990's [2]. This work has, for example, shown the role of vortices and pressure fields as agents of angular momentum transfer in ion-atom collisions. Figure 1 shows how vortices contribute the principal part of the angular momentum transfer in a ion-atom collision as opposed to the rotation of the electronic probability density about the target atom center.

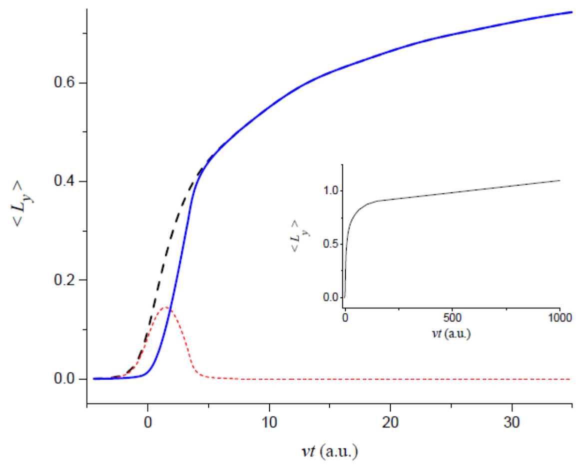

Figure 1. The y-projection of angular momentum as a function of distance *vt* in 5 keV antiproton impact of H(1s) with b=1a.u. The short dashed curve is the portion due to rotation of the electronic probability density about the proton and the dashed curve is that due to rotation about the vortex centers [1].

Complementing this fundamental insight, recent work utilizing techniques for treating ion-atom collisions developed over decades has enabled creation of large, comprehensive sets of data for applications, for example, to treat the transport of solar wind protons through the heliosphere [3,4] and the precipitation of magnetospheric ions into the polar atmosphere of Jupiter [5].

References

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