

POSITION-MOMENTUM AND INTERPARTICLE CORRELATIONS IN THE MOSHINSKY ATOM

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ABSTRACT. Correlation is a key factor in understanding a variety of chemical and physical phenomena. There are three clear sources of statistical correlations in multiple-particle quantum systems: (1) that which arises from the indistinguishability requirement on the wave function; (2) that which originates from the interaction between particles through a potential; (3) and that which is due to the uncertainty principle as a result of the noncommutativity of operators. These, and their interrelations, are schematized in the figure below. These statistical correlations manifest themselves through the nonseparability of the distribution functions describing the systems. In the first two cases (indistinguishability and interaction), the problem can be addressed, in position space (correlation between x_1 and x_2) or in momentum space (correlation between p_1 and p_2), by analyzing the nonseparability of the pair distributions of the system. The differences between the relative strength of correlation in the two different spaces are discussed in this work and related to the symmetry of the wave function and the strength of the interparticle potential. In the case of position-momentum correlation (which also occurs in one-particle systems), the problem must be formulated in terms of the Wigner function, a quantum phase-space representation of the system.

Proposals to distinguish between the different kinds of statistical correlations are of fundamental importance to determine their effects on the behavior of a system. Additionally, there is the question of how one kind of correlation is related to another, e.g. how the position-momentum correlation is affected by the presence of an interparticle potential.

In this work, analyses of statistical correlation are made with the measures provided by Information Theory, i.e. mutual information, which is defined in terms of the Shannon entropies of the corresponding one- and two-particle densities.

We study a two-particle analytically solvable model known as the Moshinsky atom. In the first part we discuss the statistical correlation between the particles positions and between their momenta, and how the relative strength of the correlation is governed by the potential. In the second part we analyze position-momentum correlation at one and two particle-levels through the one- and two-particle Wigner functions and quantities defined in analogy with mutual information. In this case, a scheme which permits the separation of the position-momentum correlation from the interaction correlation, is proposed.

We also discuss the delocalization phenomena in all the distributions from analysis of their Shannon entropies.

