Manifestation of Relative Phase in Dynamics of Two Interacting Bose-Bose Droplets

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Our work is devoted to the dynamics of two interacting Bose-Bose quantum droplets. Such droplets are self-bound mixtures of two atomic Bose-Einstein condensates. Our main finding is that the dynamics of these macroscopic objects depend on the relative phases of the droplets' wavefunctions. We confirm that two identical droplets may merge, as was shown in the Florence group experiments, but also that more exotic scenarios are possible. For instance, one of the droplets may disappear, transferring some atoms to its neighbor and evaporating the remaining ones, or the droplets may repel each other altogether. All these effects depend purely on the very quantum feature of the droplet – its phases. The observed phenomenon of two coupled supercurrents bears a close resemblance to the Josephson effect. Using this analogy and utilizing the concept of Goldstone modes, we introduce a Josephson junction-like formalism describing the dynamics of atomic density and relative phases of the droplets. The interplay of the relative phases and the atomic supercurrent determines the motion and dynamics of a droplet pair. We also discuss the occurrence of entertainment between the two supercurrents, known as the hitherto experimentally elusive Andreev-Bashkin effect. The processes studied in this work have analogues in collisions of atomic nuclei; they are also at the heart of recently observed supersolids formed by arrays of quantum droplets with dipole-dipole interactions. The dynamics of coupled droplets are thus at the intersection of atomic, condensed matter, and nuclear physics. We believe that the phenomena predicted for two-droplet collisions will guide future experiments.