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Vortex 'molecules', a hydrodynamic analog for hadrons

Hydrodynamic analogs constitute a rich field with ties to every area of physics – including quantum foundations, via the walking droplet pilot-wave system and the nascent field of hydrodynamic quantum analogs. Vortex 'molecules', theoretical bound states of fractionally-quantized vortices in multi-component Bose-Einstein condensates (BECs), provide a hydrodynamic analog for hadrons in a theory of SU(2) quantum chromodynamics in 2+1 space-time dimensions. Similarly to the walking droplet system, an oscillatory driving field leads to the unique dynamics: when each component of a BEC is a different hyperfine state of the same atom, one can introduce a Rabi (Josephson) coupling between them, allowing for these states with hadron-like properties. In a two-component BEC, a vortex will be attached by a sine-Gordon soliton to either an antivortex in the same component or to a vortex in the other component, creating a 'meson' or 'baryon', respectively, by analogy. When the connecting soliton is stretched to a critical length, it breaks creating a vortex-antivortex pair, demonstrating confinement of the fractionally-quantized vortices similarly to quark confinement in QCD. One can identify topological quantities with quantum numbers, i.e. the total circulation or winding with the baryon number, and the winding of the relative phase between the two components with the color charge. The low-energy effective theory of two-component BECs is an extension of Polyakov's dual photon model in 2+1 dimensions, a model which can be obtained as a low-energy effective theory of an SU(2) gauge field similar to QCD.