Bohmian trajectories and nonlocality in relativistic two-photon interactions

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Bohmian mechanics is a nonlocal hidden-variable interpretation of quantum theory which predicts that particles follow deterministic trajectories in spacetime. Historically, the study of Bohmian trajectories has mainly been restricted to nonrelativistic regimes due to the widely held belief that the theory is incompatible with special relativity. Contrary to this belief, my collaborators and I recently developed a new approach for constructing the relativistic Bohmian-type velocity field of single particles via weak measurements of the particle's momentum and energy [1].

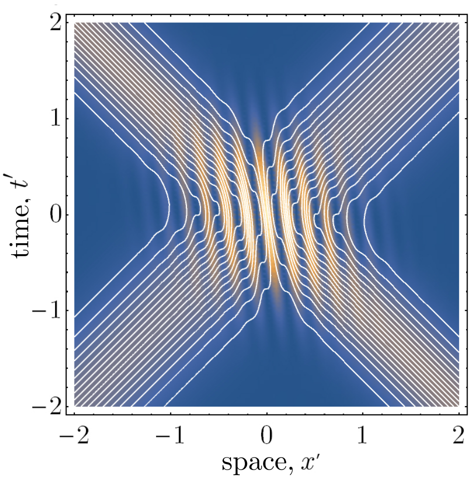

Figure 1: Relativistic Bohmian trajectories of single photons in a Mach-Zehnder interferometer.

In this talk, I present an extension of our relativistic Bohmian theory to include multi-particle interactions. Starting from our weak measurement model, I show that the resulting two-photon velocity field can be reinterpreted in terms of the Lorentz-covariant components of the Klein-Gordon conserved current vector, thus inheriting the intrinsic relativistic properties of the dynamical theory. I apply our velocity equation to a two-photon position-symmetrised state, calculating the Bohmian-type trajectories in the resulting bunched interference pattern. These trajectories demonstrate how nonlocality manifests in relativistic interactions from the Bohmian interpretation. I discuss the future outlook of our research especially regarding the reformulation of our model to account for scenarios involving partcle creation and annihilation processes.

[1] Joshua Foo, Estelle Asmodelle, Austin P. Lund, and Timothy C. Ralph, *Nature Communications* **13**, 4002 (2022).