Asymptotic Charge Induced Decoherence in QED and Quantum Gravity

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In QED and (linearized) quantum gravity, we show that any localized charge will eventually decohere in the momentum basis in an asymptotically flat spacetime. This places an upper bound on the size of any coherent quantum superposition in space, and also generates an enhanced rate of wavepacket spreading. We estimate the size of these effects, which arise because any massive (or charged) particle necessarily radiates soft, entangling gravitons/photons to null infinity as it evolves. In the limit of infinite time–such as in QED scattering theory–this soft radiation gives rise to superselection in the electron momentum basis, with the result that almost all scattering states exhibit total delocalization of the charges. It is an experimental fact that this does not obstruct accurate predictions for collider experiments, where the central-momentum dependence of scattering cross sections can still be calculated. Nevertheless, in regimes where quantum coherence of charged particles becomes important, this total loss of coherence in traditional scattering theory is a fundamental obstacle to realistic predictions. In QED scattering, realistic physics only survives within a small class of carefully dressed states. In (nonlinear) quantum gravity, the conclusion is different, and suggests that valid physical states in quantum-gravitational scattering theory can only be described in terms of relational observables, e.g. by the introduction of extended objects.

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