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Locality and the phase space representation of quantum fields

The Hegerfeldt theorem asserts that any localized state of a relativistic particle would become delocalized in an arbitrarily short time. We derive a phase space representation of non-relativistic and relativistic quantum fields that circumvents this problem by using a set of localized wave packets that are neither particles nor anti-particles. The dynamical equation of the probability amplitude takes the form of a classical Vlasov equation with quantum corrections. We discuss applications of the method, including Schwinger and Unruh effect.