Non-intercommuting Cosmic Strings

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We perform the numerical field evolution for the collision of two Abelian type I cosmic strings. We present evidence that, for collisions at small but characteristic relative velocities and angles, these cosmic strings *do not* exchange ends and separate. Rather, local higher winding number bound states are formed close to the collision point, which promote multiple local scatterings at right angles and prevent intercommutation from happening. This constitutes the simplest example of the breakdown of the intercommutation rule, usually assumed in the construction of effective models for cosmic string network evolution.

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Scenarios based on cosmic strings, formed at a Grand Unified Theory (GUT) phase transition [1] are important candidates to explain the origin of the primordial perturbations responsible for the formation of structure in the Universe [2]. Cosmic Strings may also be associated with many other important cosmological phenomena [3]. After being formed at a GUT symmetry breaking phase transition, a network of cosmic strings is thought to evolve so as to approach a universal scaling behavior, characterized by a given mean length of string per Hubble volume. In all implementations to date, this complicated evolution is assumed to be well described by a Nambu-Goto action governing the dynamics of each string, together with a rule for the outcome of the collisions between them, deduced from the original field theory of which strings are classical solutions. Our present ignorance of the details of GUTs and their string solutions makes the latter task impossible. So far detailed studies of string collisions have been limited to the simplest field theory exhibiting strings, the Abelian Higgs model. Cosmic strings formed at a GUT transition may not be Abelian, even though these solutions are the simplest.

The study of string collisions amounts to solving an infinite degree of freedom non-linear dynamical system, which can only be done numerically. Numerical scattering experiments in the Abelian Higgs model, for type II and global strings, [4–6], have confirmed the usual assumption that strings intercommute, i.e., they exchange ends at every collision. In this region of parameter space, when the Higgs mass is larger than the mass of the gauge field, the interactions between two strings with the same orientation are repulsive [7,8], leading to their separation after the collision.

Type I strings are more interesting because the static potential between them is always attractive [7,8]. As a consequence, higher winding number bound states can be formed. In particular these bound states prevent an ordered Abrikosov lattice from existing in laboratory experiments involving type I superconductors. Nevertheless, a network of type I strings is thought to be viable in the early Universe as long as the string density at formation is sufficiently low [8]. All numerical studies concerning the outcome of type I string collisions performed to date [9] were targeted at showing that, at high approach center-of-mass velocities ($v = 0.75$ with $c = 1$), two high winding number strings will form a bridge of lower winding number connecting them. This bridge then grows, promoting the peeling of the original high winding number configurations onto lower ones [9].