3D reconnection of random magnetic fields

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The problem of three-dimensional magnetic reconnection in random fields is widely discussed now both in astrophysics and fusion science. As is known, a crucial ingredient of reconnection are the null points of the magnetic field, where the condition of the magnetic flux freezing becomes broken. In the 2D approximation, the null points have a universal topology of X-type, while much more diverse configurations are possible in the 3D situation. The case that was most studied before is the axially-symmetric fan-like structure (which is called also the “proper radial null”), i.e. collision of two oppositely-directed magnetic fluxes with subsequent outflow in the equatorial plane. On the other hand, the configurations with a finite number of the fan “vanes” (or the “improper radial nulls”) were usually assumed to be the specific particular cases. However, the probability of occurrence of the various configurations was never calculated in detail.

The aim of our report is to present a self-consistent calculation of the above-mentioned probabilities in the potential field approximation. The basic results can be formulated as follows:

(i) The most likely case of the 3D reconnection (i.e., occurring with the dominant probability) is the six-tail structure, in which the magnetic field lines come out of the null point in 6 asymptotic mutually-orthogonal directions.

(ii) The axially-symmetric fan-type structure (with infinite number of vanes) is admissible but emerges with a very small probability.

(iii) The generic six-tail structure possesses 4 “dominant” and 2 “recessive” asymptotic directions and, thereby, approximately reduced at the sufficiently large scales to the well-known 2D structure of X-type. So, the specific 3D effects will manifest themselves, first of all, in the small-scale reconnection events.

The above-listed results should be important both in the analysis of astrophysical MHD turbulence and in studying the processes in the laboratory devices.