Contribution ID: **3082** Type: **not specified**

P1.1037 The Ideal Evolution Equationand Fast Magnetic Reconnection

Monday, 8 July 2019 14:00 (2 hours)

See the full abstract here:
http://ocs.ciemat.es/EPS2019ABS/pdf/P1.1037.pdf

The ideal evolution equation, ∂B/∂t =curl×(u⊥×B),implies magnetic field lines move with a velocity u⊥and cannot change their connections. Nevertheless, for an electric field that is arbitrarily close to the ideal form, E +u⊥×B= -grad Φ,magnetic connections will in general break on a time scale τ, where 1/τ≈|grad u⊥|, times the logarithm of the magnetic Reynolds number ℜm, which is |u⊥×B| divided by the deviation of the parallel electric field from the ideal form. The connections breaking part of the magnetic field is proportional to exp(t/τ)/ℜm. This mathematical theorem is proven [1] using Lagrangian coordinates, ∂x(x0,t)/∂t=u⊥(x,t), which provide an explicit solution for an ideally evolving magnetic field BI(x,t). The exact electric field defines the evolution of the Clebsch potential sinB=gradα×gradβ. This evolution can be solved an alytically for the deviation of a magnetic field from its ideal form, B -BI, while that deviation is small. The generic behavior of anear-ideal evolution provides answers to four fundamental questions on magnetic reconnection: (1) Why does the near-ideal evolution of natural and laboratory magnetic fields robustly lead to states of fast magnetic reconnection independent of the drive and of the initial state? (2)What is the characteristic time required to reach a state of fast magnetic reconnection? (3)What is the explanation of the effects produced by fast magnetic reconnection, which are primarily associated with magnetic helicity conservation and an energy transfer from the magnetic field to the plasma? (4) Why does the Alfvén speed define the time scale during which the effects produced by fast magnetic reconnection occur? A middle singular value of the Singular Value Decomposition of the Jacobian matrix ∂x/∂x0of Lagrangian coordinates is required for an exponential growth of the connections-breaking field while having a small, non-exponential, change inthemagneticfield strength. The two-dimensional assumption of traditional reconnection theories effectively excludes exponentiation. Traditional theories are inapplicable to the fast reconnection that occurs during tokamak disruptions and of problematic applicability to the astrophysical problems for which they were developed.

Work supported by U.S. Department of Energyawards DE-FG02-95ER54333, DE-FG02-03ER54696, DE-SC0018424, and DE-SC0019479.

[1] A. H. Boozer, Phys. Plasmas 26, 042104 (2019).

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Session Classification: Poster P1

Track Classification: MCF