SEMINAR NOTICE

Department of Physics and Engineering Physics
University of Saskatchewan

SPEAKER: Dr. Amir Jafari, Applied Mathematics and Statistics,
The Johns Hopkins University, Baltimore MD, USA

TOPIC*:* *Does magnetic reconnection change topology?*

DATE: Tuesday September 24th, 2024

TIME: 3:30-4:30 p.m.

PLACE: ***Physics 103***

Abstract:

We show that magnetic reconnection and topology-change can be understood, and distinguished, in terms of trajectories of Alfv\'enic wave-packets $\mathbf{x}(t)$moving along the magnetic field $\mathbf{B}(\mathbf{x},t)$with Alfv\'en velocity $\dot{\mathbf{x}}(t)=\mathbf{V}_A(\mathbf{x},t)$, i.e. adopting a Lagrangian formalism for virtual particles. A considerable simplification is attained, in fact, by directly employing elementary concepts from hydrodynamic turbulence without appealing to the fictitious and complicated notion of magnetic field lines moving through plasma. In incompressible flows, Alfv\'enic trajectories correspond to the dynamical system $\dot{\mathbf{x}}(t)=\mathbf{B}$, where $\mathbf{B}$solves the induction equation, with phase space $(\mathbf{x},\mathbf{B})$. Metric topology of this phase space, at any time t, captures the intuitive notion that nearby wave-packets should remain nearby at a slightly different time $t\pm\delta t$, unless topology changes e.g., by dissipation or turbulence. In fact, continuity conditions for magnetic field allow rapid but continuous divergence of these trajectories, i.e., reconnection, but not discontinuous divergence which would change magnetic topology. Thus topology can change only due to time-reversal symmetry breaking e.g., by dissipation. In laminar and even chaotic flows, the separation of Alfv\'enic trajectories at all times remains proportional to their initial separation, i.e., slow reconnection, and topology changes by dissipation with a rate proportional to resistivity. In turbulence, trajectories diverge super-linearly with time \textit{independent} of their initial separation, i.e., fast reconnection, and magnetic topology changes by turbulent diffusion with a rate \textit{independent} of small-scale plasma effects. The crucial role of turbulence in enhancing topology-change and reconnection rates originates from its ability to break time-reversal invariance and make the flow \textit{super-chaotic}. In fact, Lipschitz continuity of both velocity and magnetic fields is known to be lost in turbulence, which incidentally makes equations of motion singular requiring renormalization or a weak-formulation. Alfv\'enic trajectories can therefore separate rapidly even if their initial separation tends to vanish, unlike simple chaos. This super-chaotic behavior is an example of the phenomenon of spontaneous stochasticity in statistical physics, sometimes called the real butterfly effect in chaos theory to distinguish it from the butterfly effect in which trajectories can diverge quickly only if initial separation remains finite. Our results strongly support the Lazarian-Vishniac theory of stochastic reconnection.

Coffee and cookies will be available in the Physics lounge at 3:00pm for those attending the seminar.