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On-off intermittency and Lagrangian coherent structures in solar dynamo

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The aperiodic temporal behavior of solar cycles and grand minima such as the Maunder Minimum suggest a description of solar cycles as an on-off intermittency, which is an ubiquitous phenomenon in nonlinear dynamical systems (He & Chian, PRL 91, 034102, 2003; Rempel & Chian, PRL 98, 014101, 2007; Chian et al., PRL 104, 254102, 2010). The transition to an intermittent mean-field dynamo is studied using 3D numerical simulations of compressible magnetohydrodynamic turbulence driven by a helical forcing, by varying the magnetic diffusivity. Two dynamo regimes, a wave regime and an intermittent regime, are identified as the magnetic diffusivity is varied (Rempel, Proctor & Chian, MNRAS 400, 509, 2009). We report the detection of Lagrangian coherent structures (LCS), in the simulated solar dynamo, which are material lines and surfaces in the velocity field that act as barriers to particle transport and have been described as the Lagrangian building blocks of turbulence (Rempel, Chian & Brandenburg, ApJL 735, L9, 2011). There are two types of LCS formed by distinct groups of fluid particles, one of them attracts other fluid particles and the other one repels them. These barriers have been used to study turbulence and transport in fluids and plasmas through numerical simulations, laboratory experiments, and observational data in oceans and a wide range of applications. LCS reveal that the topology of transport barriers in the velocity field suffers a dramatic change when the magnetic field undergoes the transition from a wave to an intermittent dynamo. The sharp contrast between the dynamics of LCS in these two dynamo regimes permits a unique analysis of the impact of the magnetic field on the velocity field, which provides an in-depth insight to the origin of intermittency in solar cycles.