The role of geometric higher-order interactions in hysteresis behaviour of self-assembled nanonetworks

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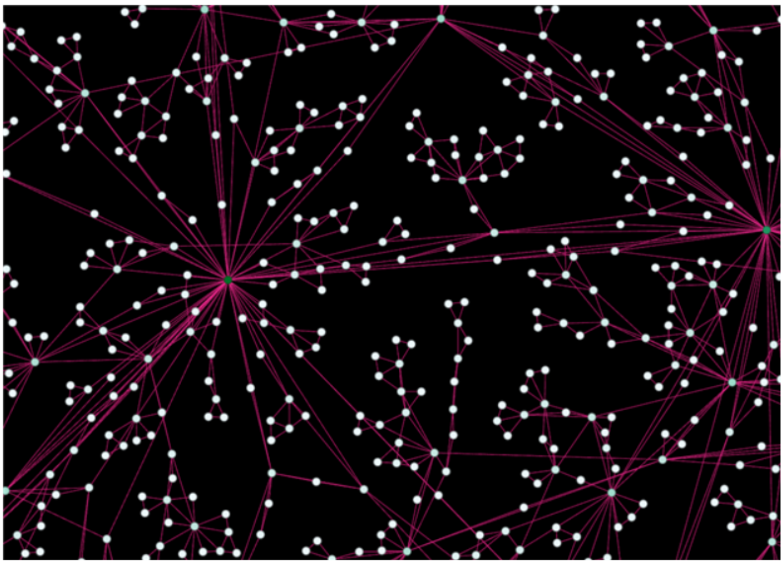

Self-assembled nanomaterials are a class of complex systems with emergent properties linked to their architecture. These materials are good examples of systems with hidden geometric features [1] that allow for higher-order interactions built into their geometry. Such interactions may affect the assembly's growth by attaching preformed groups of nanoparticles and, on the other hand, affect the assembly's emergent physical properties. By describing these systems as nanonetworks with Ising spins at the nodes and different types of interactions, researchers can study the effects of geometric frustration, built-in interactions, and the altered role of disorder [2]. In particular, this approach enables understanding how higher-order structures may affect the magnetic properties of these systems. Recent studies [3,4,5] have revealed self-organised criticality (SOC) in the hysteresis-loop dynamics, which is linked to two main types of geometric interactions, i.e., edge-based and triangle-based spin couplings.

In the presented example, we grow nanonetworks by self-assembly of nanoparticles pre-formatted in triangles, which share either a node or an edge by attachment. The Ising spins at each node can interact via both pairwise and 3-spin interactions defined by the actual triangles. When an external magnetic field is slowly applied to drive the system through a hysteresis loop, the hysteresis behaviour exhibits collective changes in magnetisation, including avalanches and a signature of SOC arising from the topological diversity of the nodes' neighbourhoods. By introducing random signs and strengths for triangle-based interactions and removing pairwise couplings, we show how the shape of the hysteresis loop and the collective spin dynamics change as a function of geometry, disorder, and induced demagnetising fields. Apart from demonstrating the complexity of controlling the magnetisation reversal processes in nanoassemblies, these findings confirm robust hysteresis-loop critical dynamics associated solely with higher-order geometric interactions [2].

References:

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