
Clustering of negative topological charges precedes plastic failure in 3D glasses

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Abstract

The deformation mechanism in amorphous solids subjected to external shear remains poorly understood because of the absence of well-defined topological defects mediating the plastic deformation. The notion of soft spots has emerged as a useful tool to characterize the onset of irreversible rearrangements and plastic flow, but these entities are not clearly defined in terms of geometry and topology. In this study, we unveil the phenomenology of recently discovered, precisely defined topological defects governing the microscopic mechanical and yielding behavior of a model 3D glass under shear deformation. We identify the existence of vortex-like and anti-vortex-like topological defects within the 3D non-affine displacement field. The number density of these defects exhibits a significant anti-correlation with the plastic events, with defect proliferation-annihilation cycles matching the alternation of elastic-like segments and catastrophic plastic drops, respectively. Furthermore, we observe collective annihilation of these point-like defects via plastic events, with large local topological charge fluctuations in the vicinity of regions that feature strong non-affine displacements. We reveal that plastic yielding is driven by several large sized clusters of net negative topological charge, the massive annihilation of which triggers the onset of plastic flow. These findings suggest a geometric and topological characterization of soft spots and pave the way for the mechanistic understanding of topological defects as mediators of plastic deformation in glassy materials.

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