How does disorder make fracture surfaces rough in brittle materials ?

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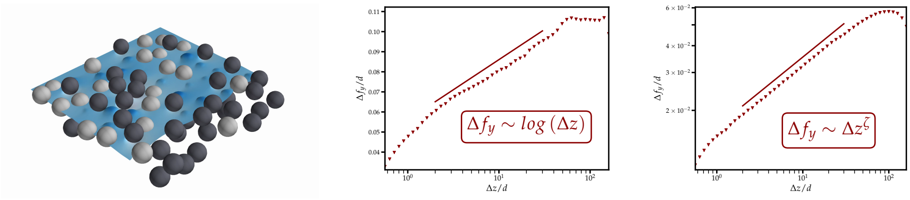
With the recent emergence of new manufacturing techniques (e.g. 3D printing), structured materials will flourish in the next few decades. Thus predicting the role played by small-scale heterogeneities on the macroscopic behavior of solids is a prerequisite to design such improved materials and make reliable predictions both on their resistance and their lifetime.

Fracture surfaces, as persistent traces of crack propagation, contain detailed information on the failure mechanisms [1]. Understanding the scale-invariant roughness of cracks by connecting fracture mechanics to critical transition theory may permit to depict the failure properties of a large range of materials with disordered microstructures within a unified theoretical framework [2].

Using perturbation methods of LEFM [3, 4], we compute the propagation of a semi-infinite crack in a heterogeneous brittle material displaying toughness discontinuities, represented by randomly distributed spherical inclusions (Fig 1.a). We apply concepts borrowed from statistical physics to characterize the resulting surface roughness [5]. We are thus able to predict rough fracture surfaces, with scaling behaviours ranging from logarithmic to self-affine (Fig 1.b & 1.c) as observed experimentally [5, 6]. The effect of various phenomena such as porosity, weak interfaces and loading imperfections on roughness are investigated and compared to experimental data.



(a) (b) (c)

Figure 1: Crack propagation (a) and scaling features predicted by our simulations - logarithmic (b) and self-affine with $\zeta = 0.32$ (c)

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