Matching microscopic and macroscopic responses in glasses with the Janus II computer

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The dynamics of glass formers (such as polymers, supercooled liquids, colloids spin glasses, superconductors,...) is so slow at low temperatures that thermal equilibrium is never reached in macroscopic samples: in analogy with living beings, glasses are said to age. Simulating aging poses such an enormous challenge that computers has been specially designed to this end. In particular, the computers Janus and Janus II, custom-built for the simulation of spin glasses, have been constructed by the Janus Collaboration, a consortium of researchers from Spain (U. Zaragoza, U. Complutense and U. Extremadura) and Italy (La Sapienza, U. di Roma and U. Ferrara).

Here, we report a study of both the linear [1] and the non-linear [2] responses of an aging spin-glass to an external magnetic field, carried out by means of large-scale simulations on Janus and Janus II.

We show that linear responses relate experimentally relevant quantities with the experimentally unreachable low-temperature equilibrium phase. We have performed a very accurate computation of the non-equilibrium fluctuation-dissipation ratio for the three-dimensional Ising spin glass. This ratio (computed for finite times on very large, effectively infinite, systems) is compared with the equilibrium probability distribution of the spin overlap for finite sizes. The resulting quantitative statics-dynamics dictionary, based on observables that can be measured with current experimental methods, could allow the experimental exploration of important features of the spin-glass phase without uncontrollable extrapolations to infinite times or system sizes.

Our study of the non-linear response emphasizes the coherence length, a crucial, yet elusive quantity in glass experiments. We first reproduce a milestone experiment that measures the spin-glass coherence length through macroscopic response (i.e. the lowering of free-energy barriers induced by the Zeeman effect). This "macroscopic" correlation length turns out to be quantitatively consistent with the coherence length estimated through the analysis of microscopic correlation functions. We also determine the scaling behavior, which allows a quantitative analysis of a new experiment [3].

[l] Janus collaboration, PNAS **114**, 1838 (2017).

[2] Janus collaboration, Phys. Rev. Lett. **118**, 157202 (2017).

[3] S. Guchhait and R. Orbach, Phys. Rev. Lett. **118**, 157203 (2017).