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Rejuvenated but remembering

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► **To cite this version:**

Eric Vincent. Rejuvenated but remembering. *Nature Physics*, 2023, 10.1038/s41567-023-02097-1 .
cea-04135494v1

HAL Id: cea-04135494

<https://cea.hal.science/cea-04135494v1>

Submitted on 21 Jun 2023 (v1), last revised 11 Jul 2023 (v2)

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The Janus Collaboration has performed massive simulations of this slow dynamics. In the present paper⁴, Baity-Jesi and colleagues have simulated a set of 160 spins interacting with their nearest neighbours through randomly distributed couplings of value ± 1 . The high computing power, together with the use of clever algorithms, allows exploring up to 10^{11} Monte Carlo steps, which means covering a remarkable time range, from 10^{-12} s up to tenths of a second, thus reaching the shorter time scale of the experiments.

In simulations, a microscopic correlation length ξ_{micro} can be defined from a 4-point correlation function, which cannot be assessed in experiments. Starting from a random configuration of the spins, which corresponds to the state of a spin glass cooled from the paramagnetic state, the growth of ‘spin-glass ordered domains’ (correlated domains in which spins flip together) has been characterized by the slow increase of ξ_{micro} (ref. 8). On the side of the experiments, macroscopic quantities are measured, like the growing magnetization obtained after cooling in zero magnetic field (that is, the ZFC procedure) and applying a small field after a waiting time t_w . The derivative of the magnetization with respect to the log of time is bell-shaped, peaking at a characteristic relaxation time t_{eff} . Aging has been discovered in the experiments as a dependence of the peak position t_{eff} on the waiting time t_w . Namely, t_{eff} is found of the order of t_w itself, which means that the dynamic properties depend on the ‘age’ t_w (ref. 7). The same aging phenomenon has been known for a long time to exist in the mechanical properties of glassy polymers¹.

Baity-Jesi and colleagues were able to simulate this experimental procedure, with bell-shaped curves peaking at $t_{\text{eff}} \approx t_w$. The breakthrough is that they also observe a rejuvenation effect when the temperature is lowered: the peak is shifted to shorter times, and, after a long aging time at the lower temperature, they find that the memory of the previous age at the higher temperature is retrieved, although rejuvenation has occurred.

Why was it so difficult to observe these effects in simulations⁸, although they have been evidenced in many experiments? To understand this point, we need to consider several length scales. Baity-Jesi and colleagues have simulated some past experiments in which another correlation length, ξ_z , was made accessible by studying the Zeeman magnetic coupling of the field with the growing spin-glass domains⁹. First, they showed that in a simple aging experiment, ξ_z and ξ_{micro} are similar. This is an important validation of the relevance of ξ_z as measured in the experiments. Second, they showed that during a rejuvenation experiment ξ_z is indeed reduced, while ξ_{micro} is untouched, keeping the memory of the previous age. Thus, the structure of the spin-glass

domains is highly non-trivial, short-length scales being reshuffled by rejuvenation while large scales are preserved. This points towards a hierarchical organization of different correlation length scales as a function of temperature, as was argued from the early experiments² (Fig. 1b). The key point is that the recent simulations can now explore sufficiently large correlation lengths (~ 16 lattice units), thus making it possible to separately investigate small-scale (from 3–6 lattice units) rejuvenation processes⁸.

Baity-Jesi and colleagues were able to examine the correlations between the spin configurations in the normal aging state, in the rejuvenated state, and in the memorized state. Strong temperature chaos is found when rejuvenation takes place, while it is absent when the same procedures are applied to a simple link-diluted ferromagnetic model. Hence, we can now understand how temperature chaos materializes in aging dynamics. The Janus Collaboration’s simulations open the way to ‘see’ how spins behave during aging, rejuvenation and memory processes. And further progress can be expected from the close collaboration that they have established with experimentalists¹⁰. Still, the dreamed breakthrough in experiments – access to the spin configurations – seems to remain out of reach despite notable efforts¹¹. The progress presently made in simulations is all the more highly appreciable.

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Published online: 19 June 2023

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Competing interests

The author declares no competing interests.