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Replica-symmetry breaking for directed polymers in random media

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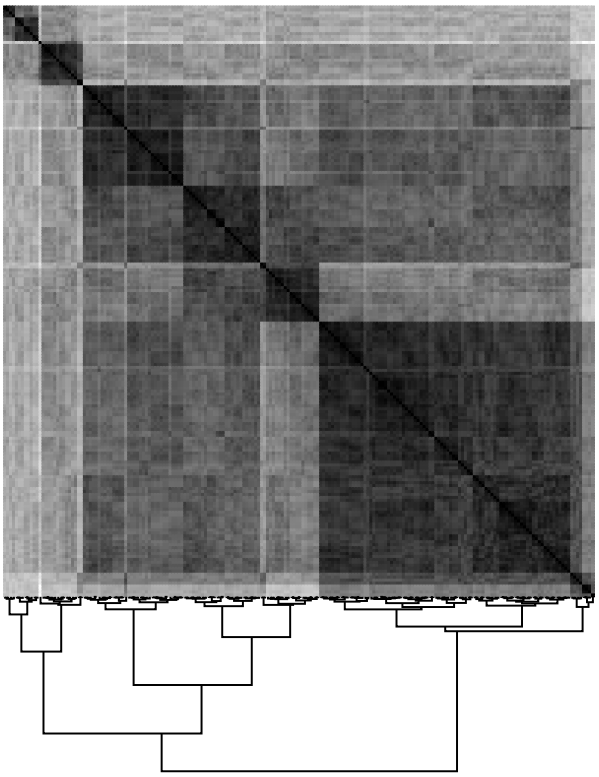

Replica-symmetry breaking (RSB) is a key concept to describe the behavior of complex physical systems. RSB was used by Giorgio Parisi end of the 1970 to solve the prototypical Ising spin glass for the mean-field case. This fertilized a strong growth of the field, and RSB was subsequently applied to many other problems like optimization problems, structural glasses, eigenvalues of random matrices or neural networks. The deep impact the concept of RSB and related work had on statistical physics was recognized by awarding 2021 the Nobel price in physics to Giorgio Parisi.

Here, an introduction to RSB and how to observe it is given, illustrated for the spin-glass case. Spin glasses are analytically and numerically hard to treat, thus, establishing the presence of RSB for the non-mean field case is challenging.

On the other hand, directed polymers are much more conveniently to simulate, and studied here numerically on (1+1)-dimensional lattices. Configurations are directly sampled in perfect thermal equilibrium for very large system sizes of up to N = 32768 x 32768 = 10^9 sites. One fractal and two disordered ensembles of the site potential are introduced. One ensemble shows a simple behavior like a (simple) ferromagnet. The other two ensembles exhibit complex behavior reminiscent of multiple replica-symmetry breaking, in particular a broad distribution of overlaps and an ultrametric structure.

In the final part, the spin-glass board game is presented. It allows one to learn about fundamentals of spin glasses and other frustrated systems, even for non-physicists.