Can a thermodynamic glass transition be induced in a model with kinetically constrained dynamics ?

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The origin of the critical slowing down of dynamics observed at low temperatures in glass-forming materials is an old-standing problem. The main question is whether the observed phenomenon is simply related to an increasingly frustrated dynamics or it is the signature of a true thermodynamic transition. We addressed this issue investigating the mechanism by which a phase transition can be induced in a prototypical model with frustrated dynamics, which is the two-dimensional (triangular) plaquette model for glasses. Our study presented in [1] took place along with a renewed interest for the glass transition in spin models with plaquette interactions, recently investigated also in [2]. Plaquette models for glasses are very appealing ones to represent the phenomenology of glass-forming systems in finite dimensions because of two main reasons: they can be solved exactly in finite dimensions and they feature no queched disorder (as supercooled liquids do). The core of our study has been the investigation of the triangular plaquette model behaviour when long-range plaquette interactions are added to the original model on the two-dimensional lattice. We have shown that the original model is extremely sensitive to these additional long-range interactions: as soon as a finite fraction of them is added we found clear signatures of a glass transition at finite temperature. The numerical study of the model with additional interactions shows an hysteresis cycle for the energy, Fig.1 (left panel), very similar to the one of models with both a ferromagnetic ground state and glass transition ; at the same time the "critical" importance of the additional long-range interactions, which is shown by the phase diagram in Fig.1 (right panel), has been proved studying the model on the Bethe lattice.

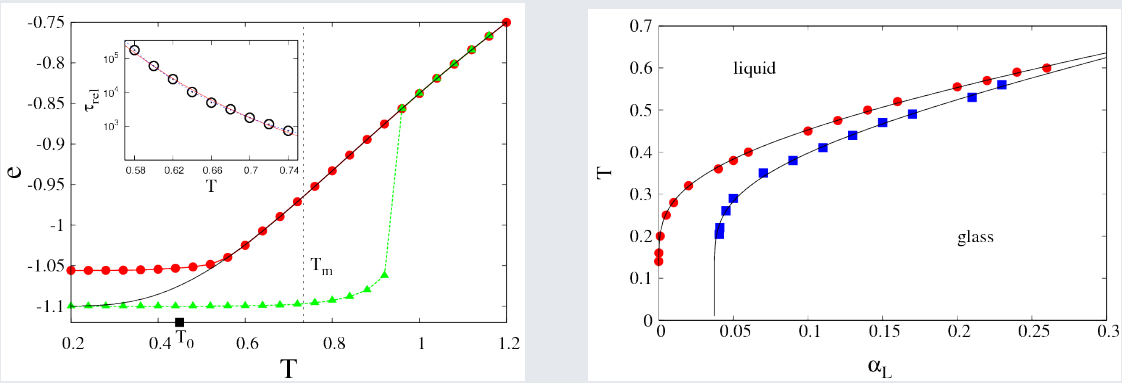

Figure: Left panel: Energy hysteresis cycle for a TPM model with additional long-range plaquettes. (Red) Circles: cooling; (Green) Triangles: heating; Continuous (black) line: high-temperature expansion. The melting temperature Tm is indicated by the dotted vertical line while the temperature T0 of the entropy crisis of the high-temperature expansion is the filled (black) square. Inset of Left Panel: Circles are relaxation time in the supercooled liquid phase as function of T, lines represents fits with Ahrrenius τ ~ exp(A/T) and Vogel-Fulcher τ ~ exp[B/(T − T_K)] laws, which work equally well. Right panel: Phase diagram of the Random Diluted-TPM model on the Bethe lattice in the (a_L, T) plane for two different values of dilution as, where aL is the concentration of long-range interactions and as the dilution of plaquettes on the of the two-dimensional lattice. Circles (red) are data for fixed dilution a_s = 1; Squares (blue) for a_s= 0.96. Continuous lines are fits of the data with the function a_L (T) = C_1 exp(− C_2 /T) + a_L(0), where C_1 and C_2 are fit parameters.

[1] S. Franz, G. Gradenigo, S. Spigler*, The Random-Diluted Triangular Plaquette Model: study of phase transitions in a Kinetically Constrained Model*, Physical Review E 93, 032601 (2016)

[2] J.P. Garrahan, *Transition in coupled replicas ma not imply a finite temperature glass transitions in glass forming systems*, Physical Review E 89, 030301 (2014)

[3] R.L. Jack, J.P. Garrahan, *Phase transitions for quenched replicas in a plaquette spin model for glasses*, Physical Review Letters 116, 055702 (2016)

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