Comment on "Hole-Burning Experiments within Glassy Models with Infinite Range Interactions"

Using a model devoid of an explicit spatial structure, in a recent Letter Cugliandolo and Iguain (CI) claim to be able to reproduce several features of nonresonant spectral hole burning (NHB) thus suggesting that NHB may not be suited to map out dynamic heterogeneity. Here we will show that the results presented by CI are not appropriate to support such a claim.

CI consider the $p = 3$ spherical spin-glass which is closely related to Leutheusser’s model of the structural glass transition [3]. They report pump frequency dependent distortions of the integrated response which they interpret as evidence for frequency selectivity, one of the main features of NHB. The model exhibits on-site (or rotational) dynamics only, thus precluding a straightforward application to translational processes. In the experimental studies addressing the rotational dynamics of glass-formers [3] frequency selective NHB signals were properly presented as evidence for dynamic heterogeneities of the $\alpha$-relaxation [4]. We have emphasized previously that [3] "it is not fully established that spatial heterogeneity is at the origin" of these observations. In this respect CI do not cite our work correctly.

Unfortunately CI have not followed the standard protocol of NHB which requires to establish metastable equilibrium prior to the pump process [6]. Merely, CI perform infinitely fast quenches from $T = \infty$ to temperatures $T = 0.8$ and $T = 0.59$. At $T = 0.8$ the waiting time is chosen as $t_w = 0$. Thus, at least at short pump durations, $t_1$, the out-of-equilibrium dynamics present in this model interfere with possible NHB effects. This is because for $T > T_c (p = 3) \sim 0.61$ the fluctuation dissipation theorem is violated on the time scale $t_\alpha$ of the $\alpha$-relaxation [5]. $t_\alpha$ tends to diverge upon approaching $T_c$. Therefore, the data reported for $T = 0.59$ again represent out-of-equilibrium dynamics and not the $\alpha$-relaxation as required for a direct comparison with the experimental results [3]. Interestingly, upon increasing $t_w$ the apparent frequency selectivity seen for the lower temperature in Fig. 7 of Ref. 1 diminishes. Thus a scenario is approached for which $t_1$ dependent NHB signals exhibit the same shape and only differ in their amplitudes.

An absence of frequency selectivity is the hallmark of homogeneous dynamics [3]. Observations of homogeneous relaxations for the $p = 3$ model would not be surprising, since (for $T > T_c$) the $\alpha$-relaxation of this model is known to proceed in an exponential fashion [5]. At a given $T$ this implies the existence of a unique $\alpha$-relaxation time which in turn precludes observation of heterogeneity in the $\alpha$-response of this model. However, the interpretation of the effects reported at $T = 0.8$ is not only hampered by the presence of out-of-equilibrium dynamics, which could be removed by a suitable choice of $t_w$, but additionally by the fact that at $T = 0.8$ $\alpha$-process and high-frequency relaxations take place on about the same time scale. If out-of-equilibrium effects can be eliminated, it remains an interesting question whether the short-time as well as the long-time behaviors of specific models imply dynamical or even spatial heterogeneities.

In summary the study of CI reveals that out-of-equilibrium dynamics can produce phenomena which, without proper caution, can be confused with those characteristic of NHB. Hence, the results so far presented by CI do not touch upon the conclusion that the supercooled liquids studied previously do exhibit unequivocal evidence for dynamic heterogeneity [3]. We should emphasize that we do not claim that frequency selectivity is generally ruled out in models involving quenched disorder, irrespective of whether or not they exhibit a spatial structure.

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