

Campos *et al.* Reply: Our recent Letter [1] on the critical behavior of the 3D Gaussian Heisenberg spin glass (HSG), has received a Comment [2] by Campbell and Kawamura. They state that our main conclusion, namely, the chiral sector and the spin-glass sector order at the same critical temperature (i.e., $T_c^{\text{CG}} = T_c^{\text{SG}}$), is entirely based on a questionable scaling-corrections analysis [1]. Quite on the contrary, our conclusions were reached through a leading-order finite-size scaling (FSS) analysis that did not take into account any scaling corrections [1]. This analysis, presented in Table II of Ref. [1] (Table II from now on), is surprisingly not even mentioned by Kawamura and Campbell. We used the quotients method [3], a numerically convenient form of Nightingale's phenomenological renormalization [4], that has been extremely useful in the study of disordered systems [5].

Our claim [1] that $T_c^{\text{CG}} = T_c^{\text{SG}}$ follows from column six in Table II. There we showed the scaling exponent for the spin-glass (SG) susceptibility at the crossing point of the chiral glass (CG) correlation length in units of the lattice size ξ_{CG}/L . The value of $\gamma_{\text{SG}}/\nu_{\text{SG}}$ depends on the pair of lattice sizes used to extract it, (L_1, L_2) , but it tends to the sought critical exponent in the $L_1, L_2 \rightarrow \infty$ limit. Indeed, $\gamma_{\text{SG}}/\nu_{\text{SG}}$ ranges from 2.117(7) for $(L_1 = 4, L_2 = 8)$ to 1.93(2) for $(L_1 = 24, L_2 = 32)$. In whatever formulation of the spin-chirality decoupling scenario [2,6] (i.e., $T_c^{\text{CG}} > T_c^{\text{SG}}$), this exponent should tend to zero in the large volume limit. A nonzero limit, which is clearly supported by our data, implies that the SG susceptibility scales with the chiral glass correlation length.

Also in Table II were the critical exponents for the CG and SG correlation lengths $1/\nu_{\text{CG}}$ and $1/\nu_{\text{SG}}$, respectively. Note that $1/\nu$ and γ/ν carry different information (γ/ν tells us about the scaling of the susceptibility with ξ , while $1/\nu$ tells about the temperature dependency of ξ). There are two striking features in Table II. First, $1/\nu_{\text{CG}}$ and $1/\nu_{\text{SG}}$ coincide within errors for system sizes larger than 12. Second, $1/\nu_{\text{CG}}$ and $1/\nu_{\text{SG}}$ decrease rather fast with increasing L_1, L_2 . Now, at a distance ϵ from the lower critical dimension (LCD), $1/\nu$ is of order ϵ . Therefore, in both the chiral and the spin-glass sectors, the 3D HSG is closer to its LCD than thought from studies in smaller systems. On this basis, marginal behavior (i.e., lack of clear crossings of the ξ/L curves) may be expected.

Only after the above conclusions did we follow our analysis considering scaling corrections [1]. Typically, a system at its LCD has a zero critical temperature which seemed not to be the case for the HSG. This is why we used the Kosterlitz-Thouless (KT) ansatz, whose phenomenological nature was admitted [1]. KT-like logarithmic corrections account for our data. Thus, we concluded that either the LCD is barely smaller than 3 or, if the LCD is precisely 3, the critical behavior is KT-like, with $T_c > 0$.

Kawamura and Campbell are right in that we wrongly stated [1] that the scaling corrections very close to the LCD

are logarithmiclike. Indeed, it is the leading-order one that behaves almost logarithmically. FSS implies that temperature dependencies are ruled by the scaling variable $z = (T - T_c)L^{1/\nu}$. If $1/\nu$ is of order ϵ , supposedly small, in a limited range of L , the effective scaling variable will be $z \approx (T - T_c)\log L$. As a consequence, resolving crossing points of ξ/L or disentangling leading-order behavior from scaling corrections become difficult when one faces these very slow L dependencies.

Kawamura and Campbell made as well several remarks on how the typical KT behavior should be for $T < T_c$, and state that we do not observe any such KT feature [2]. Yet, their observations do not really correspond to our study, since we focused on the paramagnetic side of the critical region. It is worth mentioning here that, as we predicted [2], marginal behavior has been recently observed by Lee and Young [7]. They used parallel tempering to simulate large systems ($L = 32$) at lower temperatures than ours. Interestingly enough, in their largest systems, the ξ/L curves merged (rather than crossed) for both the chiral and the spin-glass sectors [7]. Telling exactly which kind of marginal behavior is present is a difficult problem, on which we actually did not make any strong claim [1].

I. Campos,¹ M. Cotallo-Aban,^{1,2} V. Martin-Mayor,^{3,1}

S. Perez-Gaviro,^{1,2} and A. Tarancon^{1,2}

¹Instituto de Biocomputación y Física de Sistemas Complejos
Corona de Aragón 42, Zaragoza 50009, Spain

²Departamento de Física Teórica
Universidad de Zaragoza
Zaragoza 50009, Spain

³Departamento de Física Teórica I
Facultad de Ciencias Físicas
Universidad Complutense
28040 Madrid, Spain

Received 16 April 2007; published 2 July 2007

DOI: 10.1103/PhysRevLett.99.019702

PACS numbers: 75.10.Nr, 05.10.Ln, 64.60.Fr, 75.40.Mg

- [1] I. Campos *et al.*, Phys. Rev. Lett. **97**, 217204 (2006).
- [2] I. Campbell and H. Kawamura, preceding Comment, Phys. Rev. Lett. **99**, 019701 (2007).
- [3] H. G. Ballesteros, L. A. Fernandez, V. Martin-Mayor, and A. MuñozSudupe, Phys. Lett. B **378**, 207 (1996); **387**, 125 (1996); Nucl. Phys. **B483**, 707 (1997); H. G. Ballesteros, L. A. Fernández, V. Martín-Mayor, A. Muñoz Sudupe, G. Parisi and J. J. Ruiz-Lorenzo, J. Phys. A **32**, 1 (1999).
- [4] M. P. Nightingale, Physica (Amsterdam) **83A**, 561 (1976).
- [5] H. G. Ballesteros, L. A. Fernandez, V. Martin-Mayor, A. Muñoz Sudupe, G. Parisi, and J. J. Ruiz-Lorenzo, J. Phys. A **30**, 8379 (1997); Phys. Lett. B **400**, 346 (1997); Nucl. Phys. **B512**, 681 (1998); Phys. Rev. B **58**, 2740 (1998); H. G. Ballesteros *et al.*, Phys. Rev. B **62**, 14 237 (2000); T. Jorg, Phys. Rev. B **73**, 224431 (2006).
- [6] K. Hukushima and H. Kawamura, Phys. Rev. B **72**, 144416 (2005).
- [7] L. W. Lee and A. P. Young, arXiv:cond-mat/0703770 [Phys. Rev. B (to be published)].