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8-2-1996

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Recommended Citation

arXiv:cond-mat/9608009v1

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Comment on “Moving Glass Phase of Driven Lattices”

In a recent Letter [1] Giamarchi and Le Doussal (GL) showed that when a periodic lattice is rapidly driven through a quenched random potential, the effect of disorder persists on large length scales, resulting in a Moving Bragg Glass (MBG) phase. The MBG was characterized by a finite transverse critical current and an array of static elastic channels.

They use a continuum displacement field $\mathbf{u}(\mathbf{r}, t)$, whose motion (neglecting thermal fluctuations) in the laboratory frame obeys $\eta\partial_t u_\alpha + \eta\mathbf{v} \cdot \nabla u_\alpha = c_{11}\partial_\alpha \nabla \cdot \mathbf{u} + c_{66}\nabla^2 u_\alpha + F_\alpha^p + F_\alpha - \eta v_\alpha$, where F_α is the external driving force. As in [1], we choose $F_\alpha = F\delta_{\alpha,x}$ and denote by y the $d-1$ transverse directions. GL observe that the pinning force F_α^p splits into *static* and *dynamic* parts, $F_\alpha^p = F_\alpha^{stat} + F_\alpha^{dyn}$, with $F_\alpha^{stat}(\mathbf{r}, \mathbf{u}) = \rho_0 V(r) \sum_{\mathbf{K}, \mathbf{v}=0} iK_\alpha e^{i\mathbf{K} \cdot (\mathbf{r}-\mathbf{u})} - \rho_0 \nabla_\alpha V(r)$ and $F_\alpha^{dyn}(\mathbf{r}, \mathbf{u}, t) = \rho_0 V(r) \sum_{\mathbf{K}, \mathbf{v} \neq 0} iK_\alpha e^{i\mathbf{K} \cdot (\mathbf{r}-\mathbf{v}t-\mathbf{u})}$. GL argue that in the sliding state at sufficiently large velocity \mathbf{F}^{stat} gives the most important contribution to the roughness of the phonon field \mathbf{u} , with only small corrections coming from \mathbf{F}^{dyn} . Since \mathbf{F}^{stat} is along y and only depends on u_y , they assume $u_x = 0$ and obtain a decoupled equation for the transverse displacement u_y . Analysis of this equation then predicts the moving glass phase with the aforementioned properties.

In this Comment, we show that the model of Ref. [1] neglects important fluctuations that can destroy the periodicity in the direction of motion. Following recent work by Chen et al. [2] for driven charge density waves, it can be shown [3] that the longitudinal *dynamic* force F_x^{dyn} does *not* average to zero in a coarse-grained model, but generates an effective random static drag force $f_d(\mathbf{r})$. This arises physically from spatial variations in the impurity density, and can be obtained by using a variant of the high-velocity expansion or by coarse-graining methods. To leading order in $\frac{1}{F}$ its correlations are $\langle f_d(\mathbf{r})f_d(\mathbf{0}) \rangle = \Delta_d \delta(\mathbf{r})$, where $\Delta_d \sim \Delta^2/F$, and Δ is the variance of the quenched random potential $V(\mathbf{r})$. The crucial difference from Ref. [1] is that in contrast to \mathbf{F}^{dyn} , the effective static drag force $f_d(\mathbf{r})$ is strictly \mathbf{u} -independent, as guaranteed by the precise time-translational invariance of the system coarse-grained on the time scale $\sim 1/v$.

In the presence of f_d , we now reexamine both the elasticity and the relevance of longitudinal dislocations (i.e. those with Burger’s vectors along x). An improved elastic description begins with the equation

$$\eta\partial_t u_\alpha + \eta\mathbf{v} \cdot \nabla u_\alpha = c_{11}\partial_\alpha \nabla \cdot \mathbf{u} + c_{66}\nabla^2 u_\alpha + \delta_{\alpha y} F_y^{stat}(u_y) + \delta_{\alpha x} f_d(\mathbf{r}) \quad (1)$$

Surprisingly, a simple calculation leads to a transverse correlator, $B_y(\mathbf{r}) = \langle [u_y(\mathbf{r}) - u_y(\mathbf{0})]^2 \rangle$, that is (for $d > 1$) asymptotically identical to that found by GL,

which exhibits highly anisotropic logarithmic scaling for $d \leq 3$. In contrast, the u_x roughness is dominated by f_d , and $B_x(\mathbf{r}) = \langle [u_x(\mathbf{r}) - u_x(\mathbf{0})]^2 \rangle$ grows algebraically, $\sim (\Delta_d/c_{66}^2)r^{4-d}$ for $d < 4$ and $x < c_{66}/\eta v$, crossing over for $x > c_{66}/\eta v$ (and $d < 3$) to $B_x(\mathbf{r}) \sim (\Delta_d/c_{66}\eta v)y^{3-d}H(c_{66}x/\eta v y^2)$, with $H(0) = \text{const.}$ and $H(z \gg 1) \sim z^{(3-d)/2}$. We stress that because of \mathbf{u} -independence of f_d this power-law scaling for $B_x(\mathbf{r})$ holds out to arbitrary length scales, in contrast to that for $B_y(\mathbf{r})$ valid only in the Larkin regime as lucidly discussed by GL. [1] Thus, even within the elastic description, translational correlations along x are short-ranged (stretched exponential). Stability with respect to dislocations is more delicate. Nevertheless, arguments analogous to those of Ref. [4] suggest that dislocation unbinding will occur for $d \leq 3$, converting the longitudinal spatial correlations to the pure exponential (liquid-like) form. We stress that this situation corresponds not to $u_x = 0$, as assumed in Ref. [1], but rather $\langle u_x^2 \rangle = \infty$ (indeed, u_x is *multivalued*).

We therefore argue that for intermediate velocities (for $d \leq 3$) a moving vortex solid is organized into a stack of *liquid* channels, i.e. it is a moving *smectic*. This is in agreement with structure functions and real-space images from recent simulations [5]. The model for this nonequilibrium smectic state will be the subject of a future publication [3]. An interesting possibility is that at very large velocities, nonequilibrium KPZ type nonlinearities (as in Ref. [2]) might lead to a further transition to a more longitudinally ordered state, with rather different underlying physics from the MBG.

MCM, LR, and LB were supported by the National Science Foundation, grants No. DMR-9419257, No. DMR-9625111, and No. PHY94-07194, respectively.

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PACS number: 74.60.Ge

- [1] T. Giamarchi and P. Le Doussal, Phys. Rev. Lett. **76**, 3409 (1996).
- [2] L. W. Chen et. al., Phys. Rev. B, in press.
- [3] M.C. Marchetti and Leo Radzihovskiy, unpublished.
- [4] L. Balents and M. P. A. Fisher, Phys. Rev. Lett. **75**, 4270 (1995).
- [5] K. Moon et. al., Phys. Rev. Lett., in press.