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 $F_\alpha^p = F_\alpha^{\mathrm{stat}} + F_\alpha^{\mathrm{dyn}}$, with $F_\alpha^{\mathrm{stat}}(\mathbf{r}, \mathbf{u}) = \rho_0 V(r) \times \sum_{\mathbf{K}\cdot\mathbf{v}=0} iK_\alpha e^{i\mathbf{K}\cdot(\mathbf{r}-\mathbf{u})} - \rho_0 \nabla_\alpha V(r)$ and $F_\alpha^{\mathrm{dyn}}(\mathbf{r}, \mathbf{u}, t) = \rho_0 V(r) \sum_{\mathbf{K}\cdot\mathbf{v}\neq 0} iK_\alpha e^{i\mathbf{K}\cdot(\mathbf{r}-\mathbf{v}t-\mathbf{u})}$. GL argue that in the sliding state at sufficiently large velocity $\mathbf{F}^{\mathrm{stat}}$ gives the most important contribution to the roughness of the phonon field $\mathbf{u}$, with only small corrections coming from $\mathbf{F}^{\mathrm{dyn}}$. Since $\mathbf{F}^{\mathrm{stat}}$ is along y and depends only 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 $1/F$ 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 $\mathbf{F}^{\mathrm{dyn}}$, 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 Burgers vectors along x). An improved elastic description begins with the equation

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

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 $d = 3$. 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 $B_x(\mathbf{r}) \sim (\Delta_d / c_{66} \eta v) \times y^{3-d} H(c_{66} x / \eta v y^2)$, with $H(0) = \mathrm{const}$ 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 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 of those of Ref. [4] suggest that dislocation unbinding will occur for $d < 3$, converting the longitudinal spatial correlations to the pure exponential (liquidlike) form. We stress that this situation corresponds not to $u_x = 0$, as assumed in Ref. [1], but rather to $\langle u_x^2\rangle = \infty$ (indeed, u_x is *multivalued*).

We therefore argue that for intermediate velocities (for $d \leq 3$) the vortices organize into a stack of *liquid* channels, i.e., 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.

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Leon Balents,[1] M. Cristina Marchetti,[2] and Leo Radzihovsky[3]
[1]Institute for Theoretical Physics
University of California
Santa Barbara, California 93106-4030
[2]Physics Department
Syracuse University, Syracuse, New York 13244
[3]Physics Department
University of Colorado, Boulder, Colorado 80309

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[1] T. Giamarchi and P. Le Doussal, Phys. Rev. Lett. **76**, 3408 (1996).
[2] L. W. Chen *et al.*, Phys. Rev. B (to be published).
[3] M. C. Marchetti and Leo Radzihovsky (unpublished).
[4] L. Balents and M. P. A. Fisher, Phys. Rev. Lett. **75**, 4270 (1995).
[5] K. Moon *et al.*, Phys. Rev. Lett. **77**, 2778 (1996).

