Interfaces in Driven Ising Models: **Shear** Enhances Confinement

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Shearing-
the **Ising** model?

Suppression of Thermally Excited Capillary Waves by Shear Flow

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We investigate the thermal fluctuations of the colloidal gas-liquid interface subjected to a shear flow parallel to the interface. Strikingly, we find that the shear strongly *suppresses* capillary waves, making the interface smoother. This phenomenon can be described by introducing an effective interfacial tension σ_{eff} that increases with the shear rate. The increase of σ_{eff} is a direct consequence of the loss of interfacial entropy caused by the flow, which affects especially the slow fluctuations. This demonstrates that the interfacial tension of fluids results from an intrinsic as well as a fluctuation contribution.

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Wind blowing across a lake causes the water surface to ripple. This rippling is resisted by both interfacial tension and gravity. The same forces act at a microscopic scale on capillary waves that exist as a result of thermal agitation [1–3]. In this Letter we provide the first visual evidence that, contrary to what happens for wind driven waves, flow strongly suppresses thermal interfacial fluctuations. To explain this, we present a simple model based on the idea that shear mostly affects the slow modes, since these couple the strongest to the flow. The observed interface smoothening will have repercussions for the understanding of the flow in, for example, micro- and nanofluidics [4] and during the process of droplet coalescence [5]. In addition,

point (sample A), the other farther removed (sample B). A sample was loaded into the shear cell, which was placed on a Leica TCS-SP2 inverted confocal scanning microscope equipped with a 100×1.4 NA oil immersion objective, and allowed to fully phase separate for 24 h. For details of the setup and its performance, we refer to Ref. [17]. Briefly, the shear cell is a counterrotating cone-plate cell. The bottom plate consisted of a 6 cm diameter No. 1 cover slip, while the metal cone had an angle of 1°. By rotating them in opposite directions, a simple shear flow was created with a (nearly) horizontal plane of zero velocity (ZVP). Objects in this plane remain stationary with respect to the lab frame while shearing. The vertical position of the

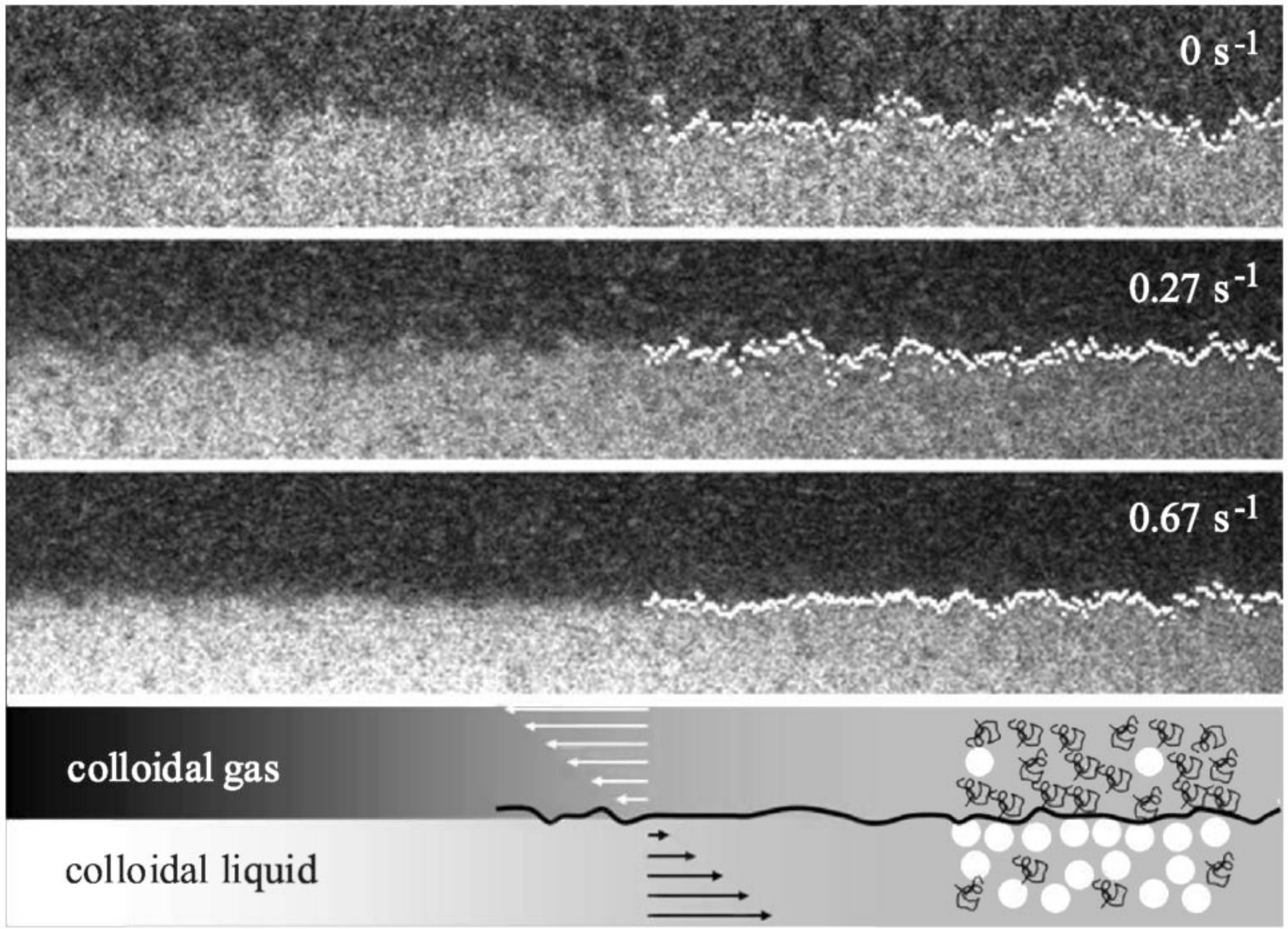

FIG. 1. Snapshots of the interface of sample A, closest to the critical point, at three shear rates. Each image is $18 \times 106\ \mu m^2$ and shows a vertical cross section through the interface. The position of the interface is indicated with bright pixels. The bottom panel schematically shows the flow geometry with the plane of zero velocity located at the interface.

Shearing- the **Ising** model?

K.-t. Leung, K. K. Mon, J. L. Vallés, and R. K. P. Zia, Phys. Rev. B **39**, 9312 (1989); K.-t. Leung and R. K. P. Zia, J. Phys. A **26**, L737 (1993).

E. N. M. Cirillo *et al.*, Phys. Rev. E **72**, 026139 (2005).

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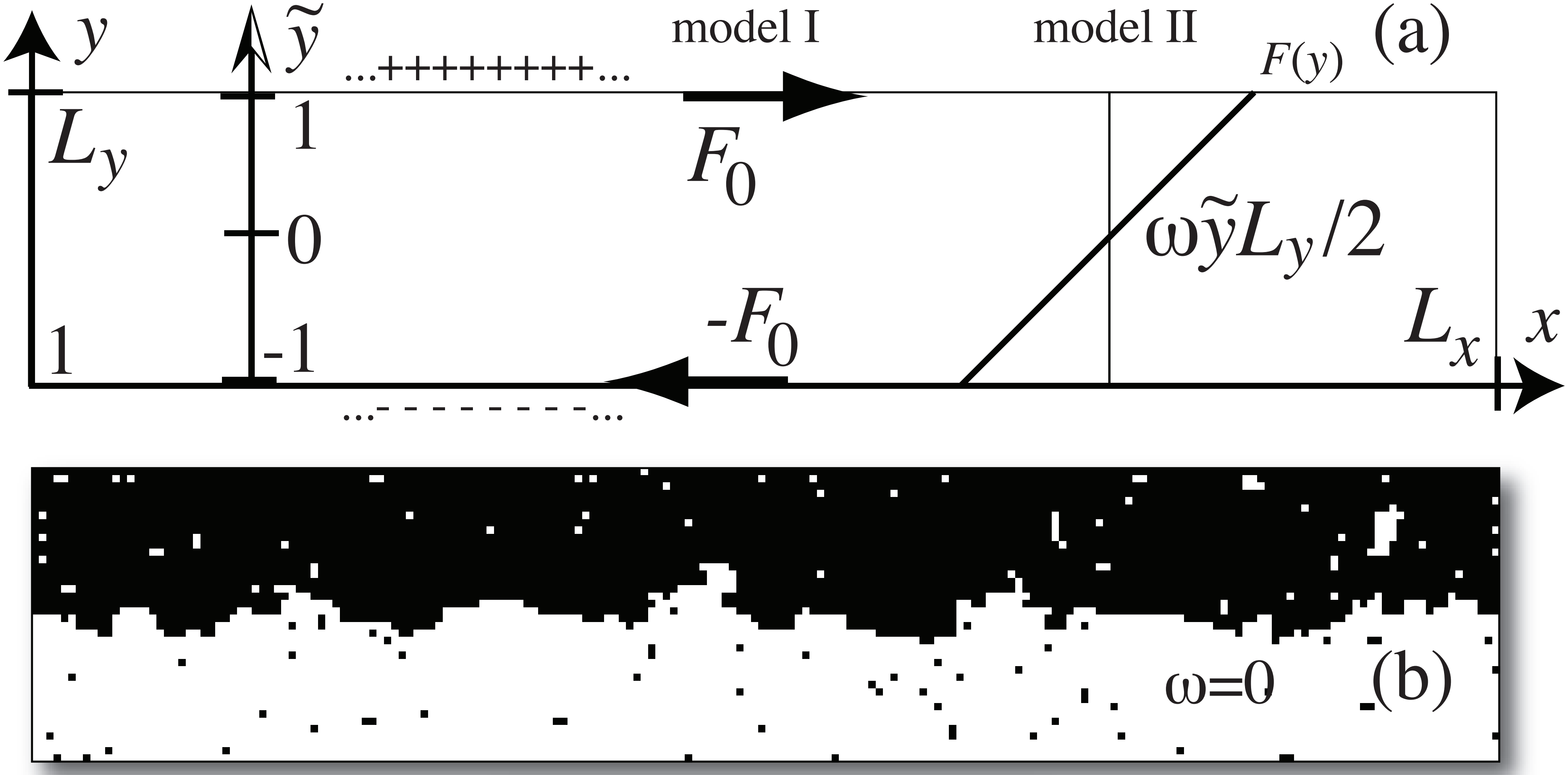
B. Schmittmann and R. K. P. Zia, in *Phase Transitions and Critical Phenomena*, edited by C. Domb and J. L. Lebowitz (Academic, London, 1995), Vol. 17, p. 1.



$$H = -J\sum_{<ij>}\sigma_i\sigma_j$$

multispin coding method

multi-threaded

model I

$F(L_y) = F_0$ and $F(1) = -F_0$, and $F(y) = 0$ otherwise;

model II

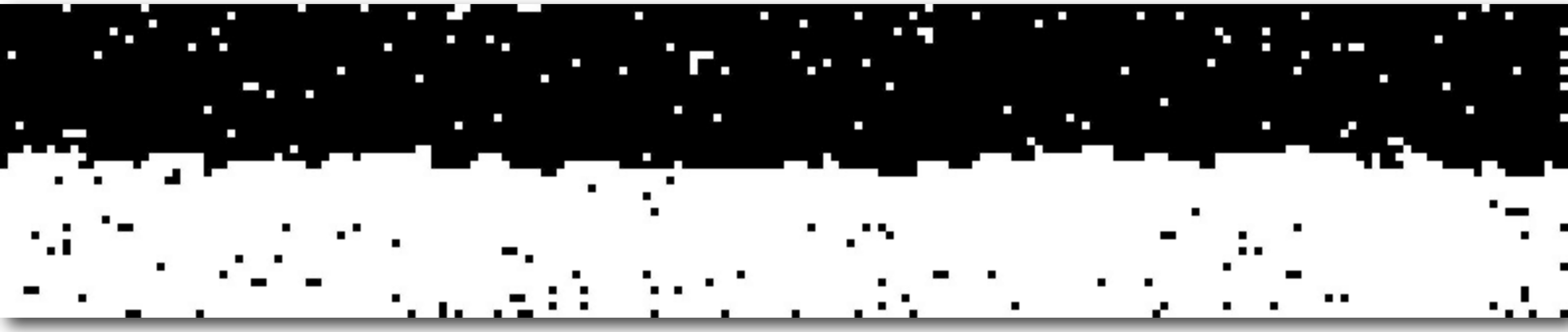
$F(y) = \omega[y - (L_y + 1)/2]$,

modified Metropolis acceptane rate

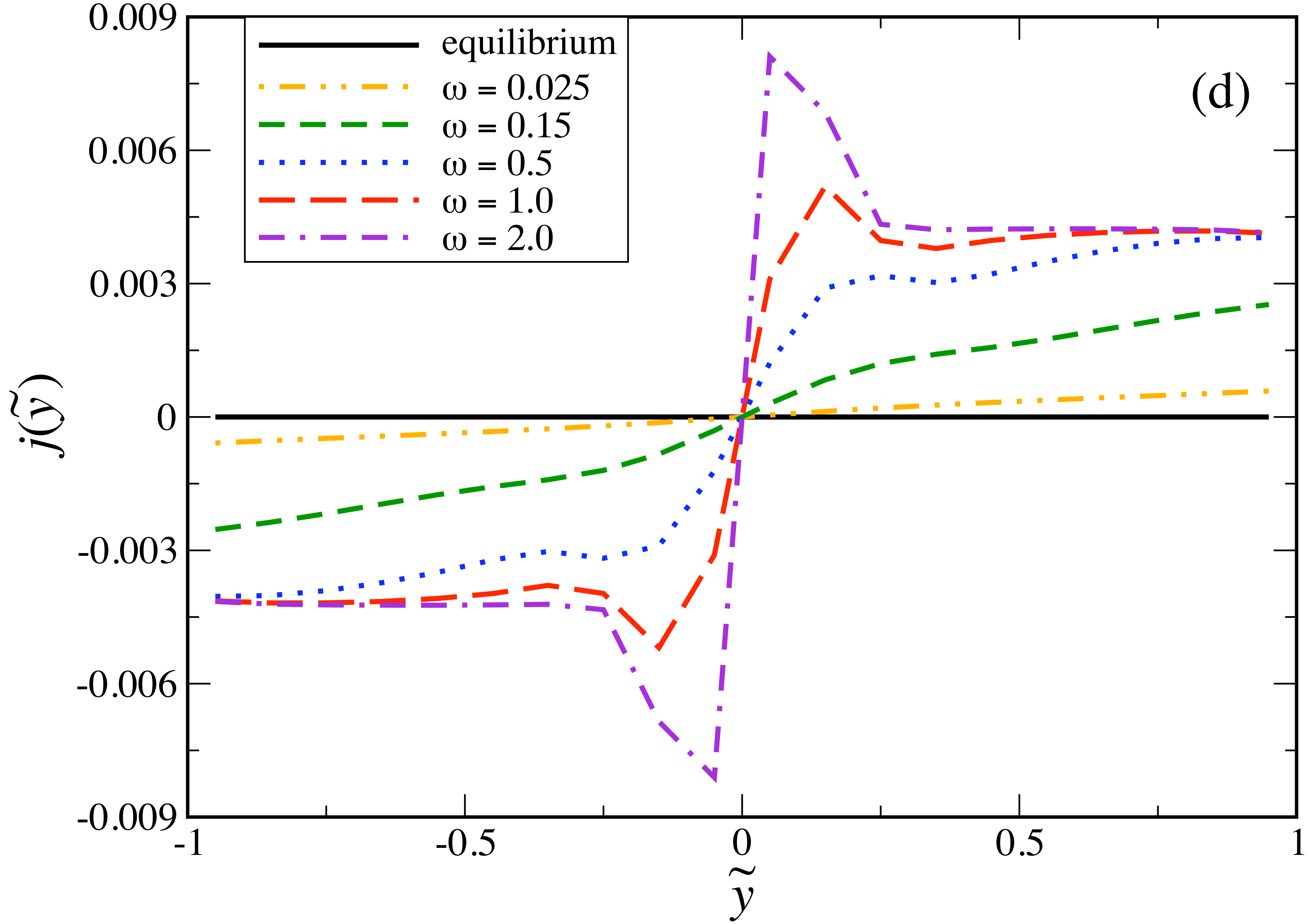
$\min\{1, \exp[-(\Delta H + \Delta F)/(k_B T)]\}$

lattice gas and magnetic language

$\tau_i = (\sigma_i + 1)/2 = 0, 1.$



Current profile

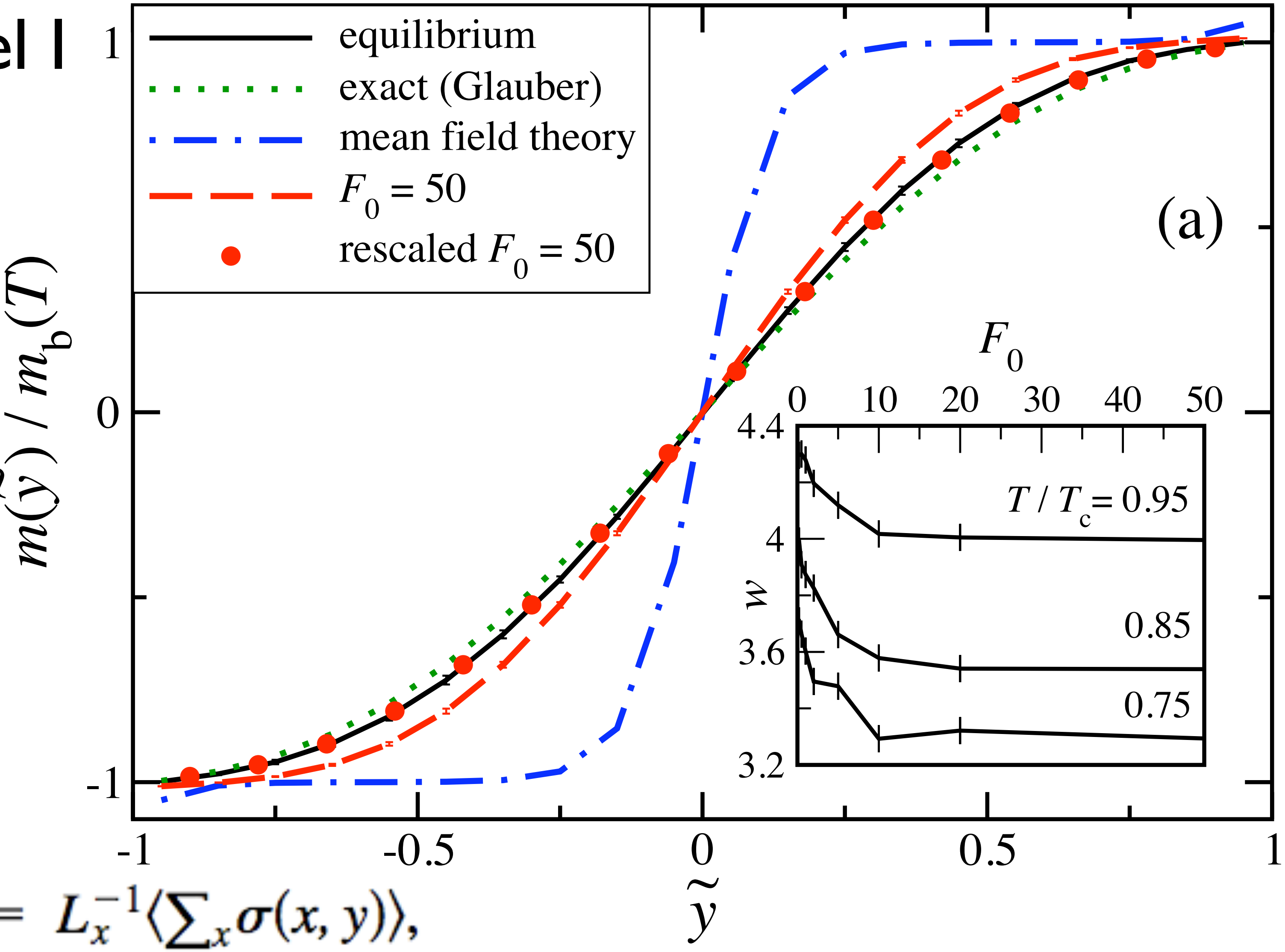


Drive acts as effective confinement

$$\frac{m(y)}{m_b(T)} \approx \mathcal{M}_{\mathrm{eq}}\left(\frac{y}{L_y^\star}\right) + \mathcal{M}_{\mathrm{corr}}(y) \quad \text{with} \quad L_y^\star < L_y,$$

Magnetization profile

model I

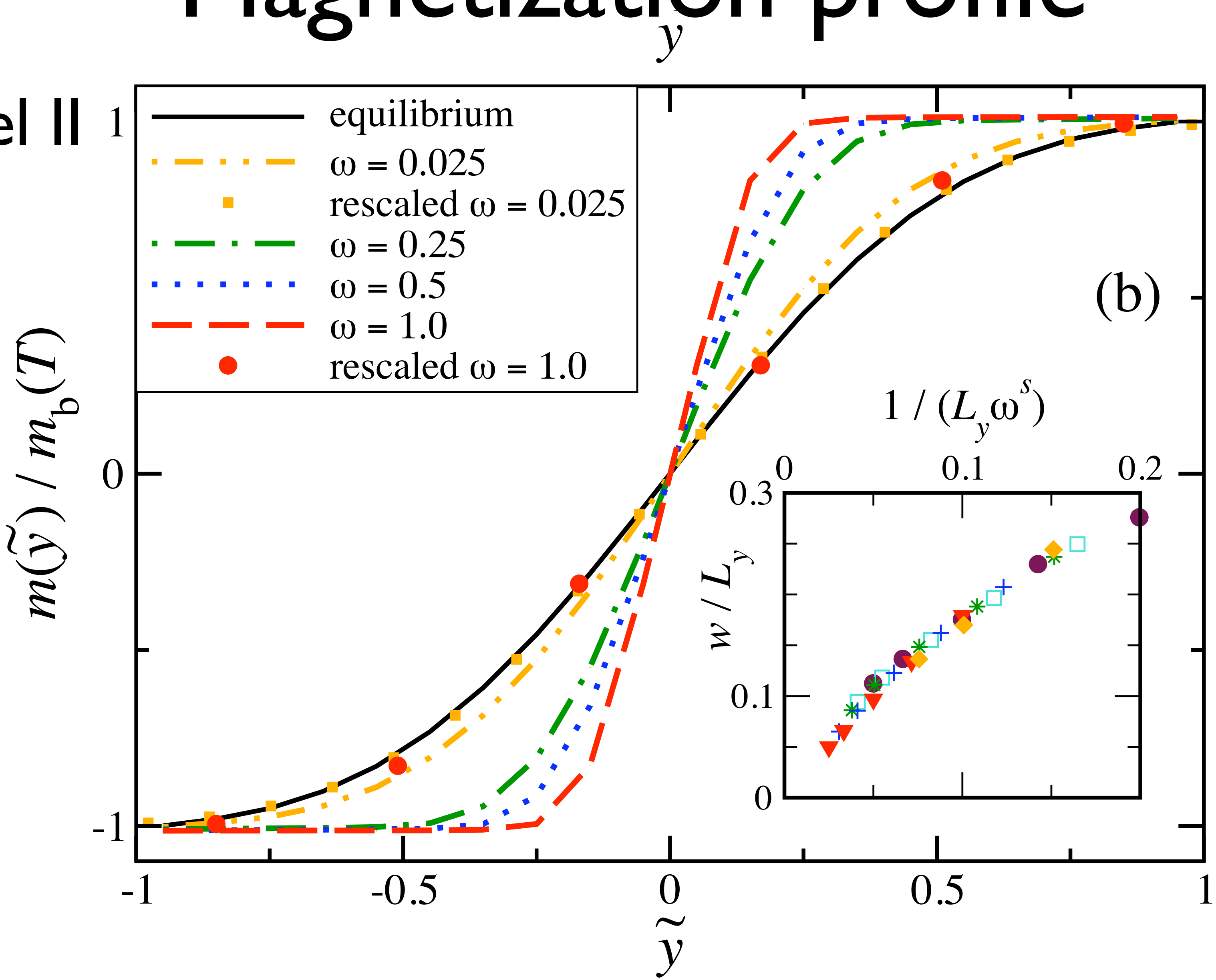


$m(y) = L_x^{-1} \langle \sum_x \sigma(x, y) \rangle,$

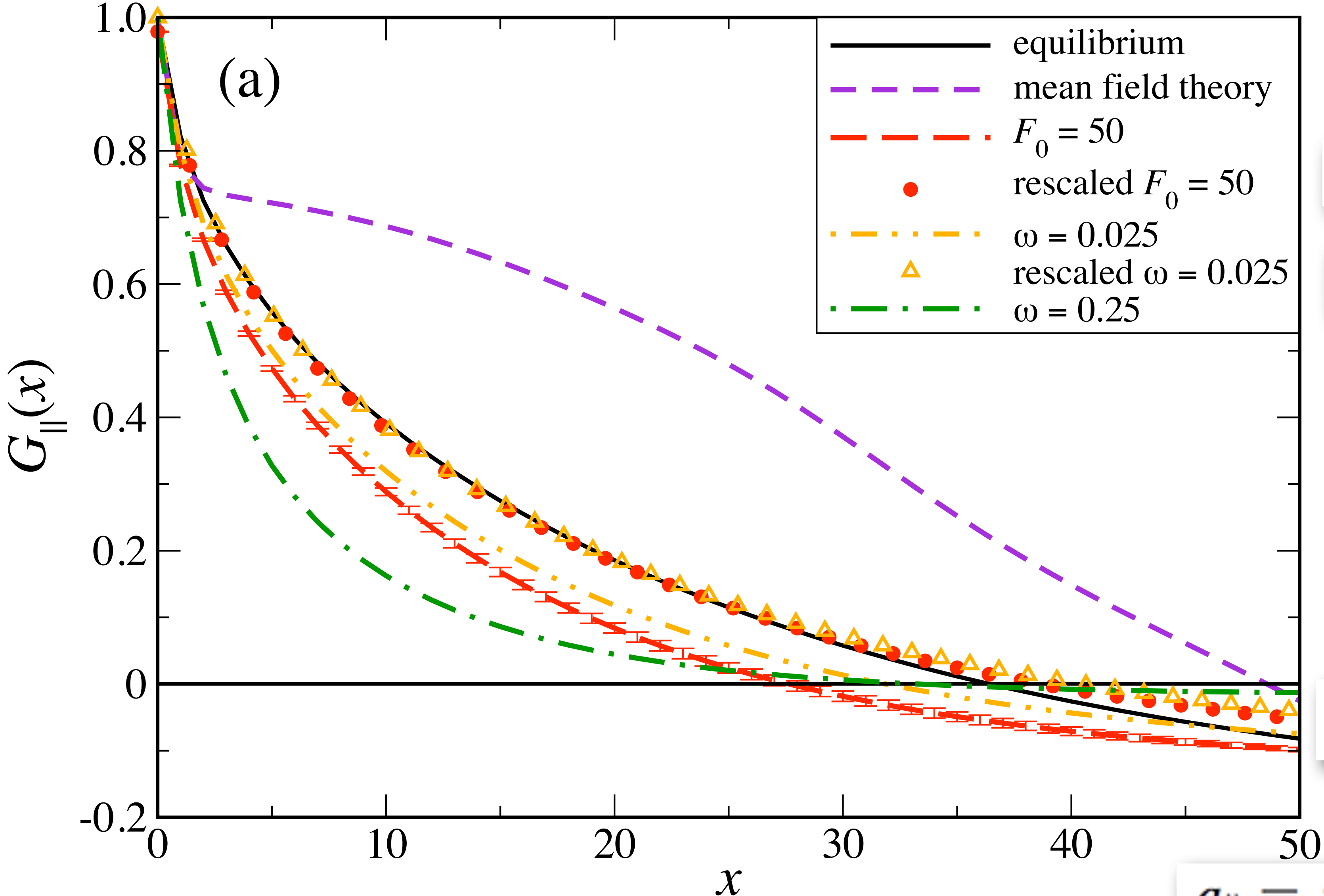
$a_\perp = L_y^\star / L_y = 0.83$

Magnetization profile

model II



Spin-spin correlation function



$G_{\|}(x/1.4)$;

$G_{\|}(x/1.27)$.

$G_{\|}(a_{\|}x) \approx$

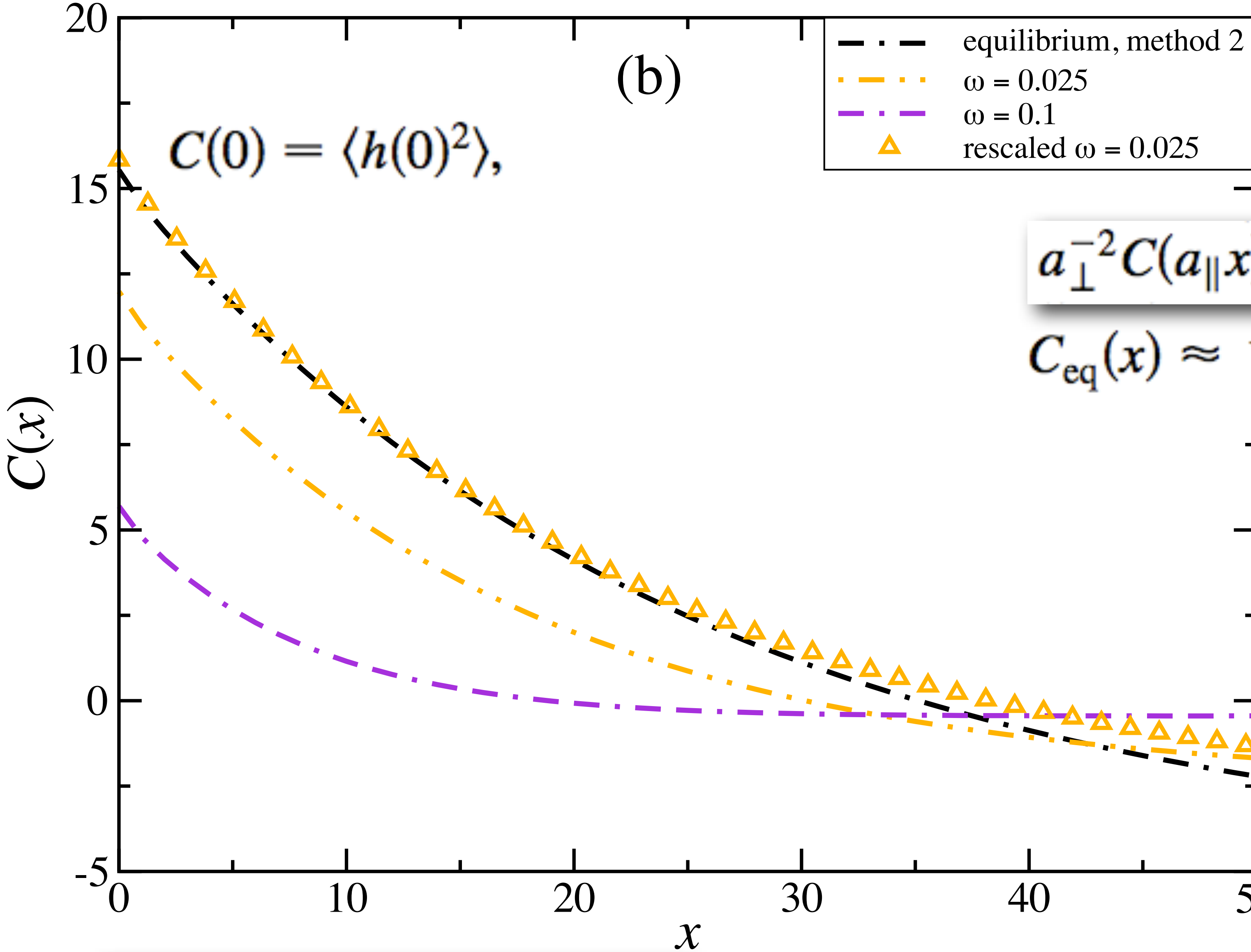
$G_{\|}^{\mathrm{eq}}(x)$.

$a_{\|} = \xi_{\|}/\xi_{\|}^{\mathrm{eq}} < 1$

$G_{\|}(x) \equiv G(x, L_y/2, L_y/2)$;

$G(x, y, y') = \langle \sigma_i \sigma_j \rangle$, where $i = (0, y)$ and $j = (x, y')$,

Coarse-graining



$$a_\perp^{-2} C(a_\parallel x) \approx C_{\rm eq}(x),$$

$$C_{\rm eq}(x) \approx w^2 \mathcal{C}(x/\xi_\parallel^{\rm eq}),$$

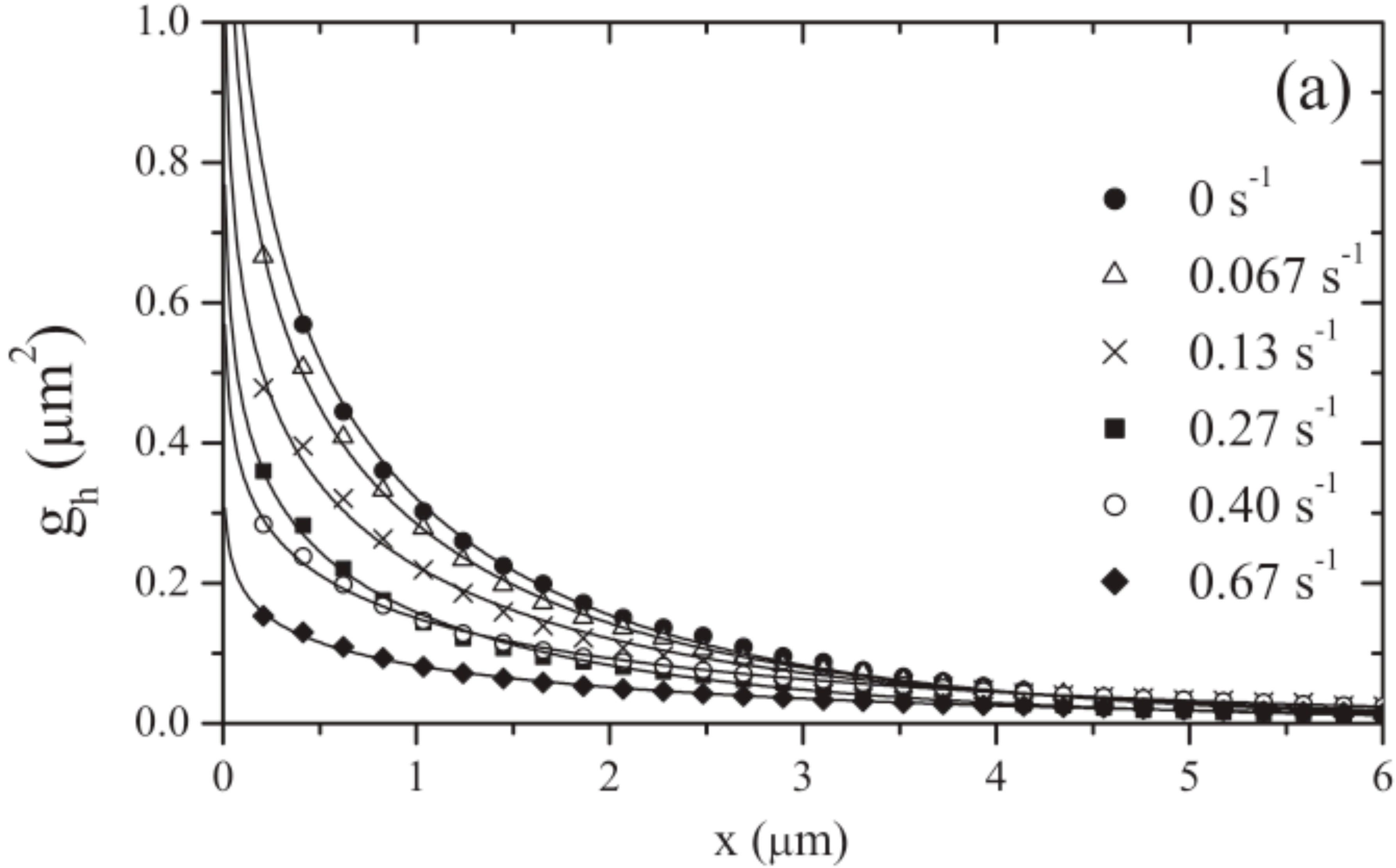
(Weeks scaling)

$$h(x) = (2m_b)^{-1} \sum_y \sigma(x, y);$$

$$C(x) = \langle h(x) h(0) \rangle = (4m_b^2)^{-1} \sum_{y,y'} G(x, y, y').$$

Experimental result

PRL **97**, 038301 (2006)



Experimental result

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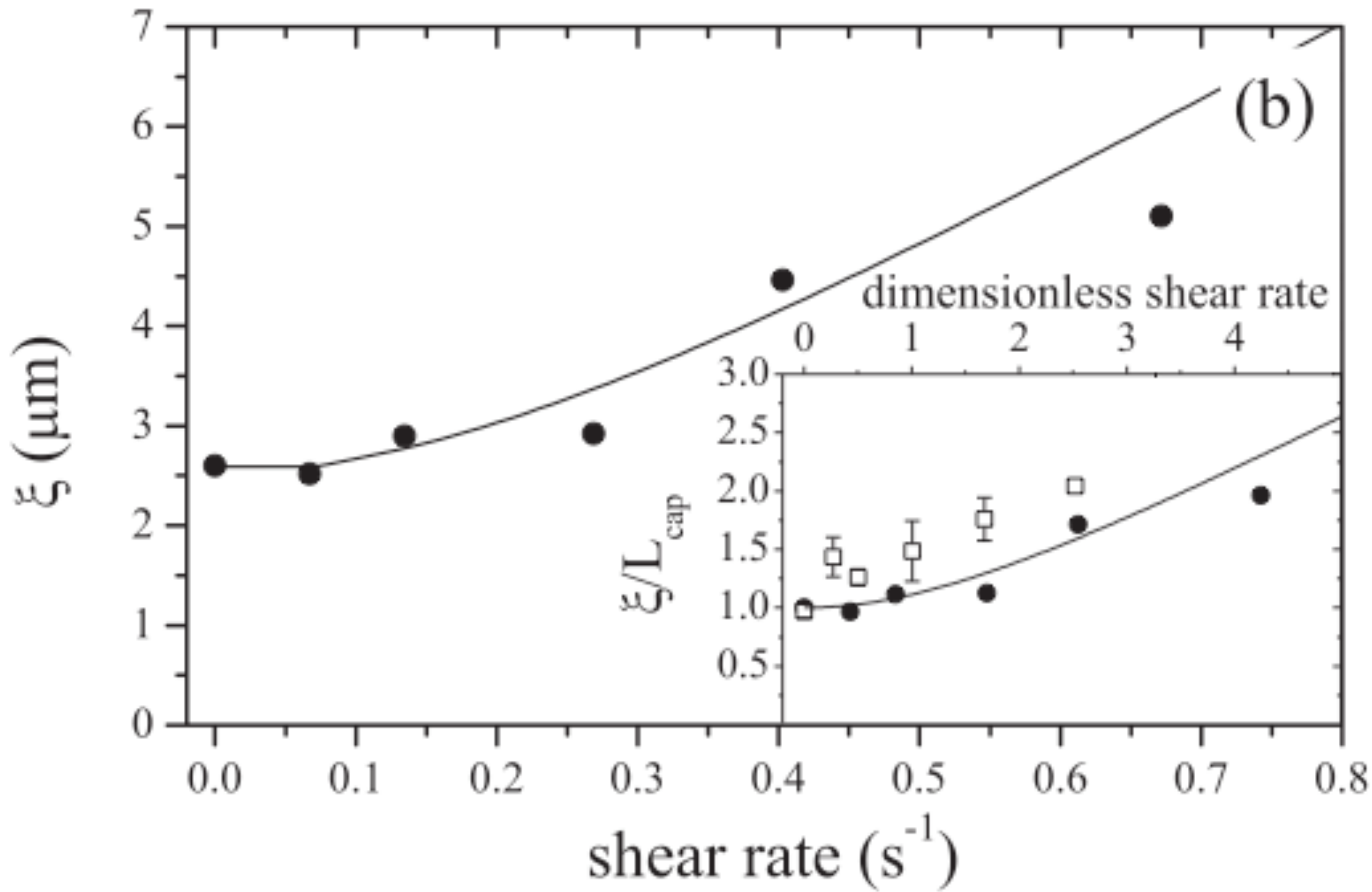

Our study: $a_{\parallel} = \xi_{\parallel}/\xi_{\parallel}^{\mathrm{eq}} < 1$

Interfaces in confined Ising models: Kawasaki, Glauber and sheared dynamics
T. H. R. Smith, O. Vasilyev, D. B. Abraham, A. Maciolek, and M. Schmidt, J. Phys.: Condens. Matter

PRL 101, 067203 (2008) PHYSICAL REVIEW LETTERS week ending 8 AUGUST 2008

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