

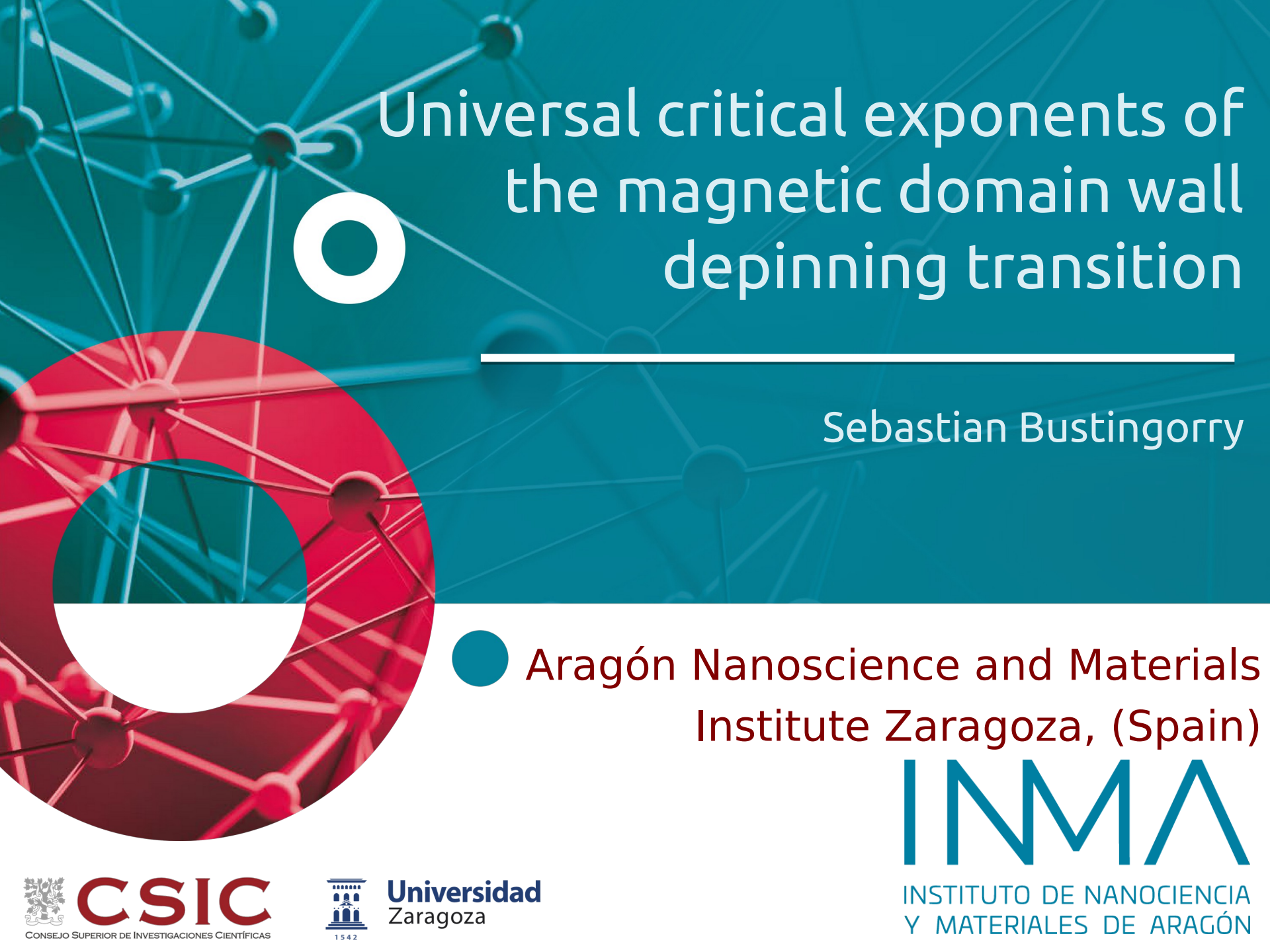
Universal critical exponents of the magnetic domain wall depinning transition

Sebastian Bustingorry

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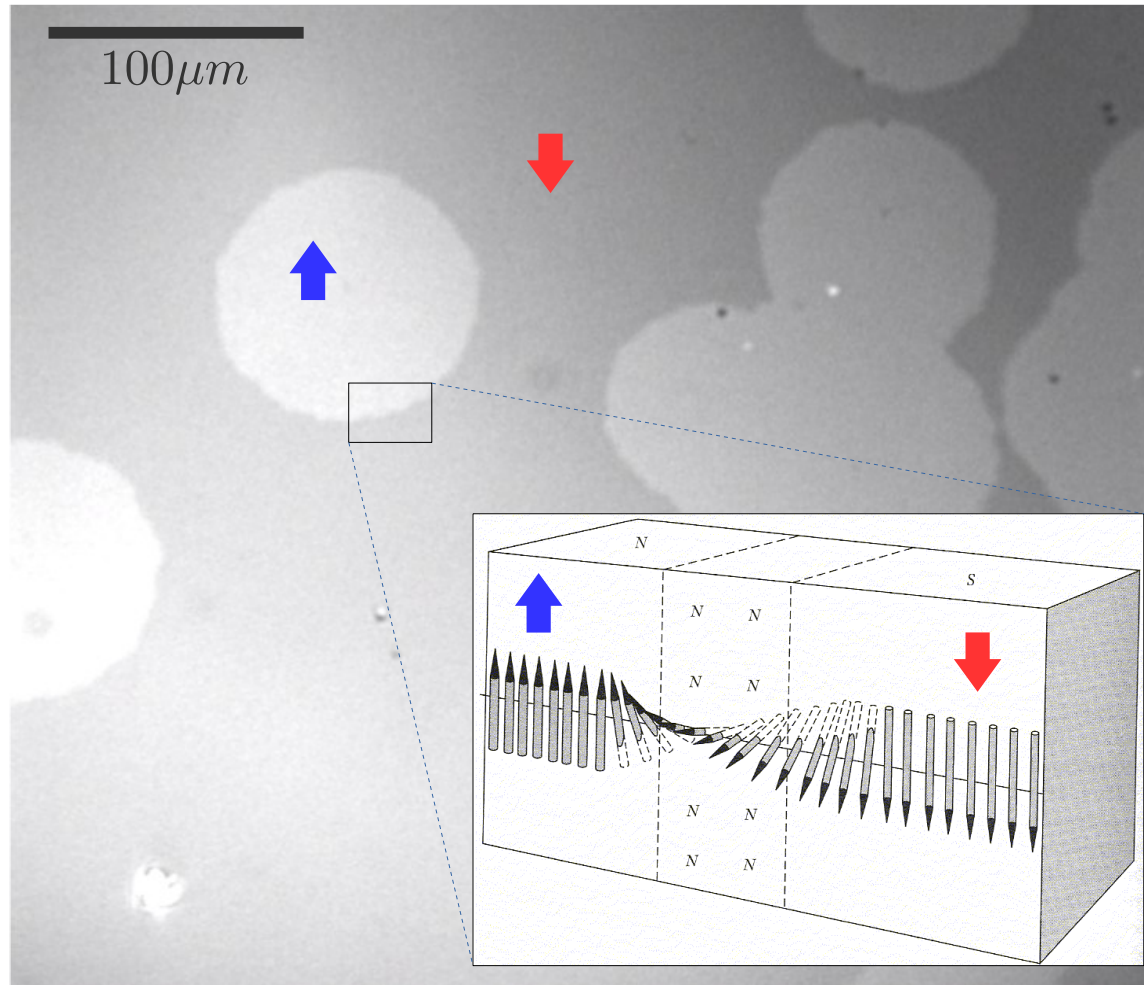
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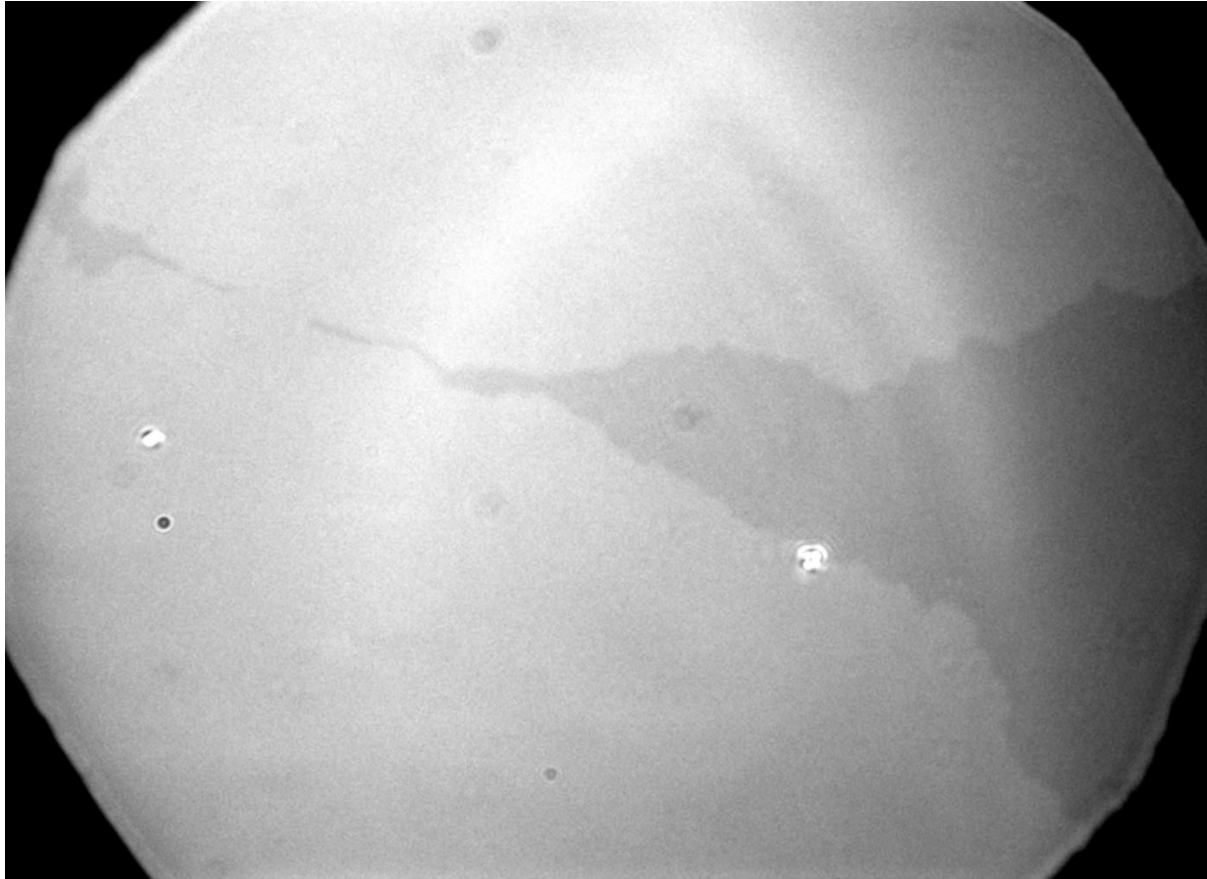
Sebastian Bustingorry

- Aragón Nanoscience and Materials Institute Zaragoza, (Spain)

INMA

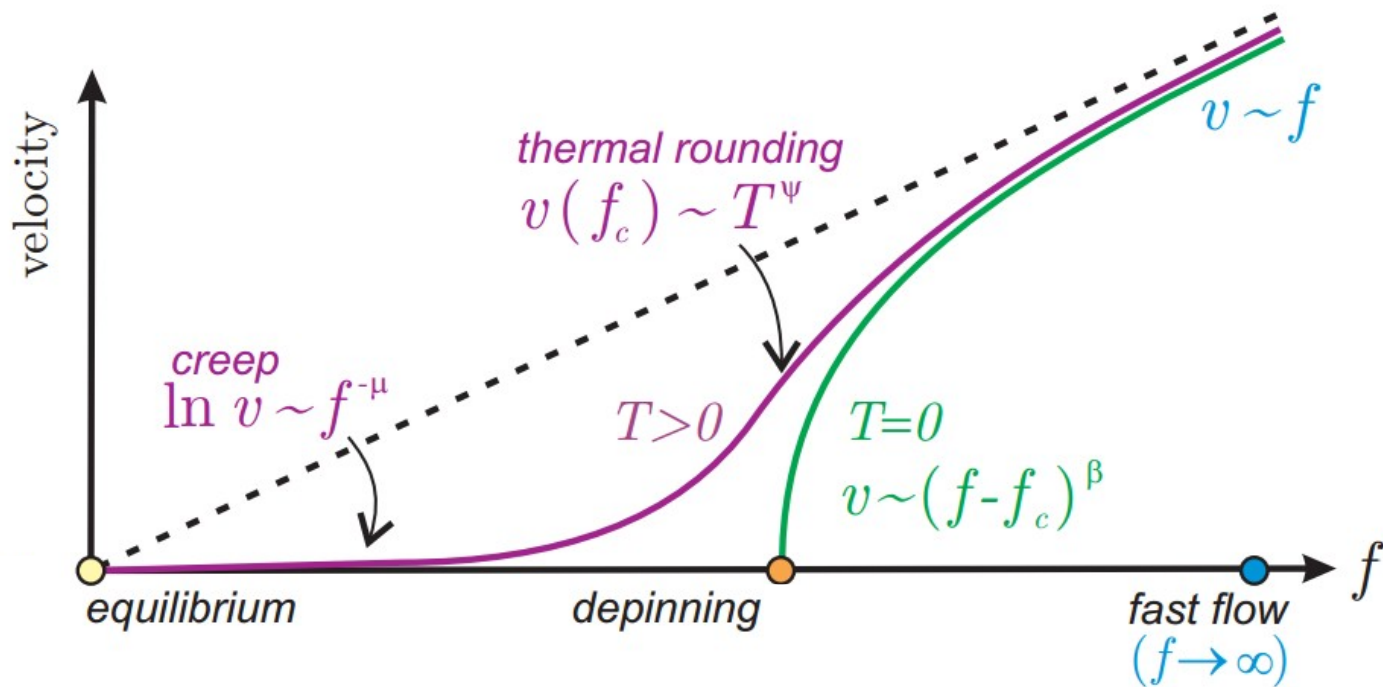
INSTITUTO DE NANOCIENCIA
Y MATERIALES DE ARAGÓN



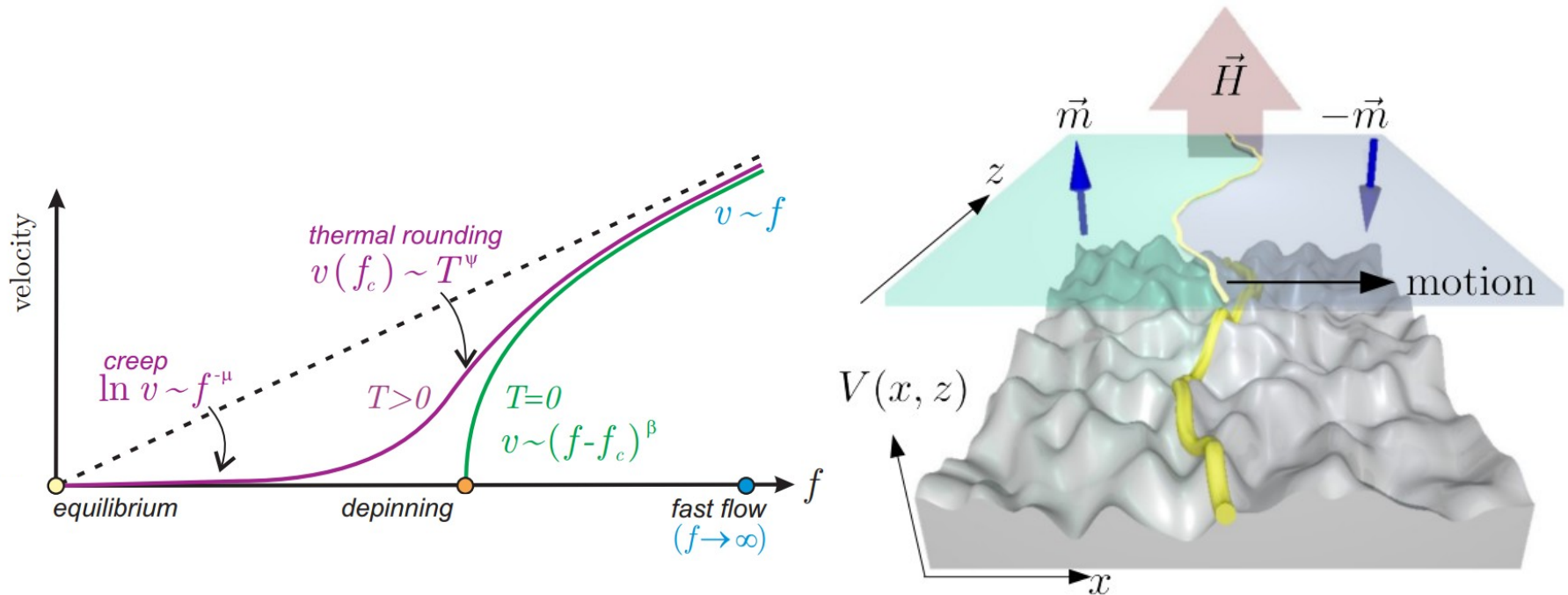


100 μm

depinning transition



depinning transition



Elastic string model

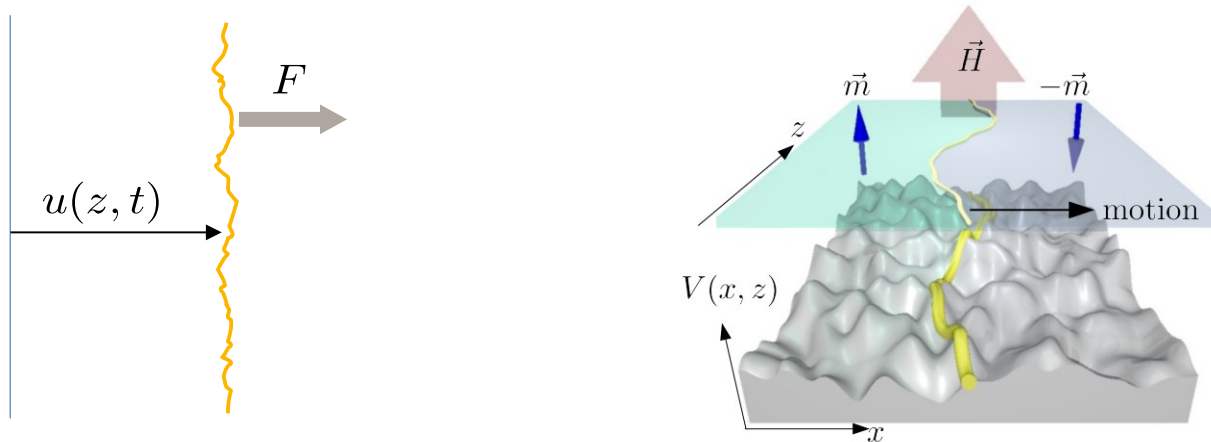
universality

Quenched Edwards-Wilkinson universality class (q-EW)

$$\frac{\partial u(z, t)}{\partial t} = c \frac{\partial^2 u(z, t)}{\partial z^2} + F + \sqrt{T} \eta(z, t) + D \xi(u, z)$$

Quenched Kardar-Parisi-Zhang universality class (q-KPZ)

$$\frac{\partial u(z, t)}{\partial t} = c \frac{\partial^2 u(z, t)}{\partial z^2} + \lambda \left(\frac{\partial u(z, t)}{\partial z} \right)^2 + F + \sqrt{T} \eta(z, t) + D \xi(u, z)$$



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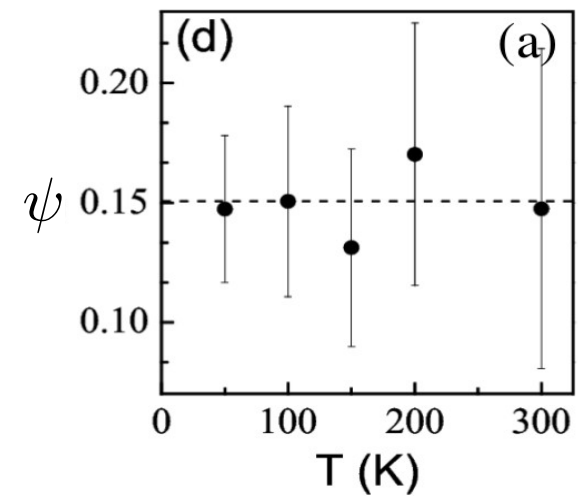
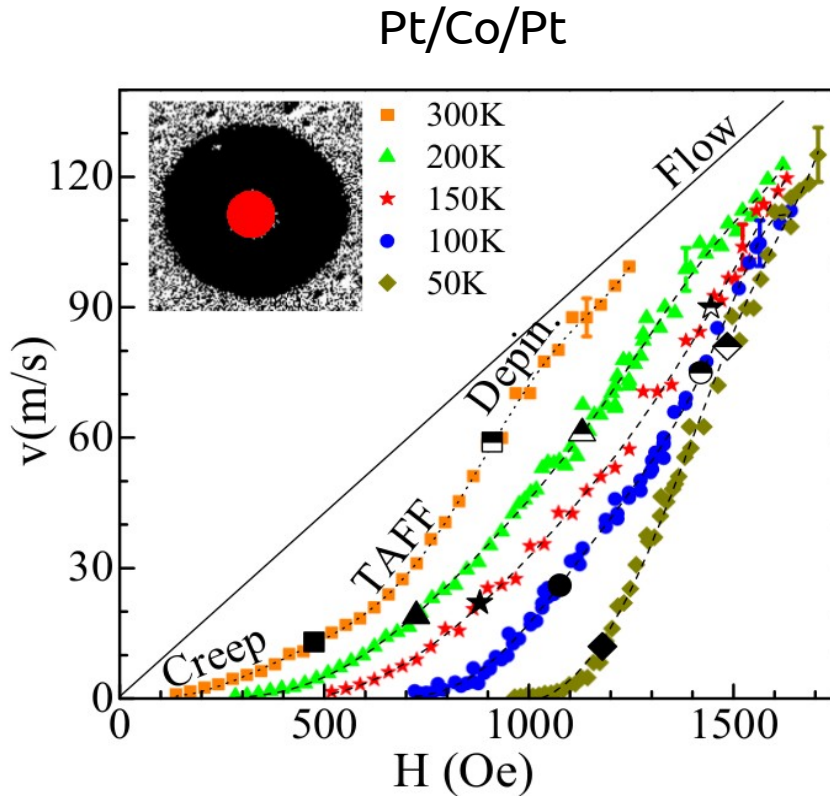
	exponent		qEW	qKPZ
order parameter	β	$v \sim (H - H_d)^\beta$	$0.245 \pm 0.006^*$ $0.33 \pm 0.02^\dagger$	$\sim 0.64^\ddagger$
correlation length	ν	$\xi \sim (H - H_d)^\nu$	$1.333 \pm 0.007^*$	$\sim 1.73^\ddagger$
thermal rounding	ψ	$v \sim T^\psi$	$0.15 \pm 0.01^{**}$?

* Ferrero, Bustingorry, Kolton, PRE (2013)

† Duemmer, Krauth, PRE (2005)

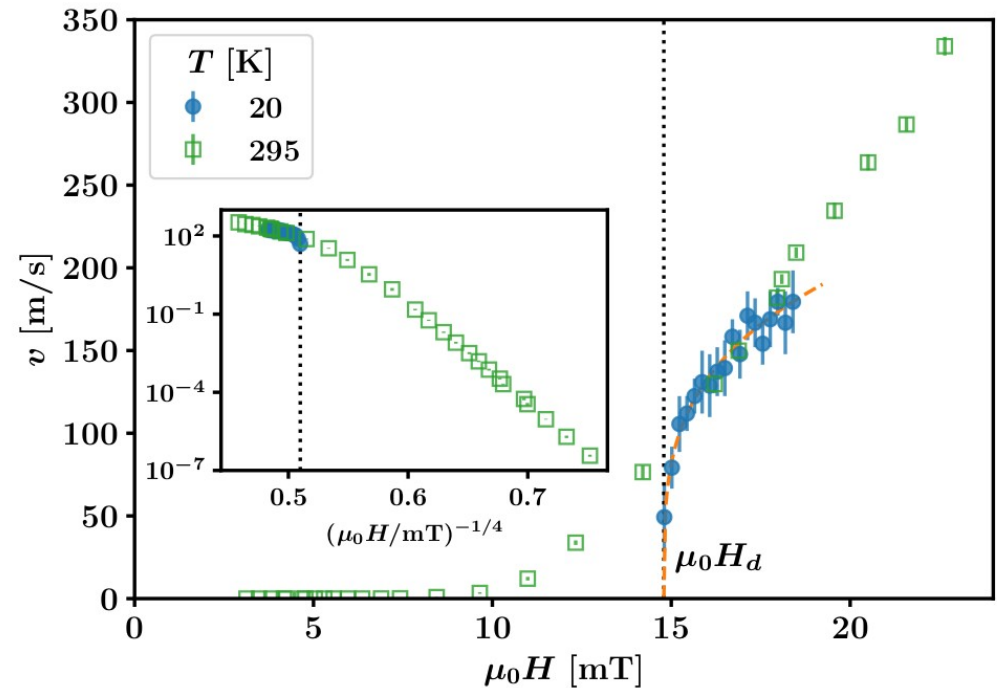
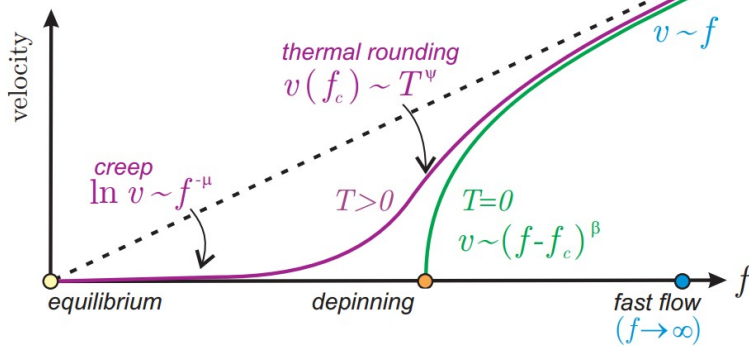
** Bustingorry, Kolton, Giamarchi, EPL (2008)

‡ Tang, Kardar, Dhar, PRL (1995)

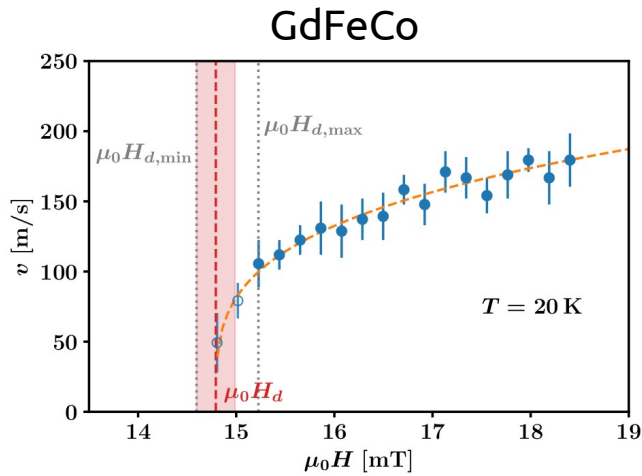


$$\psi = 0.15$$

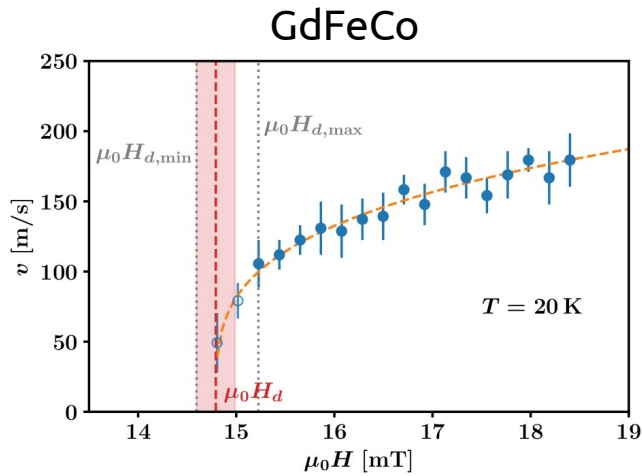
GdFeCo Velocity measurements



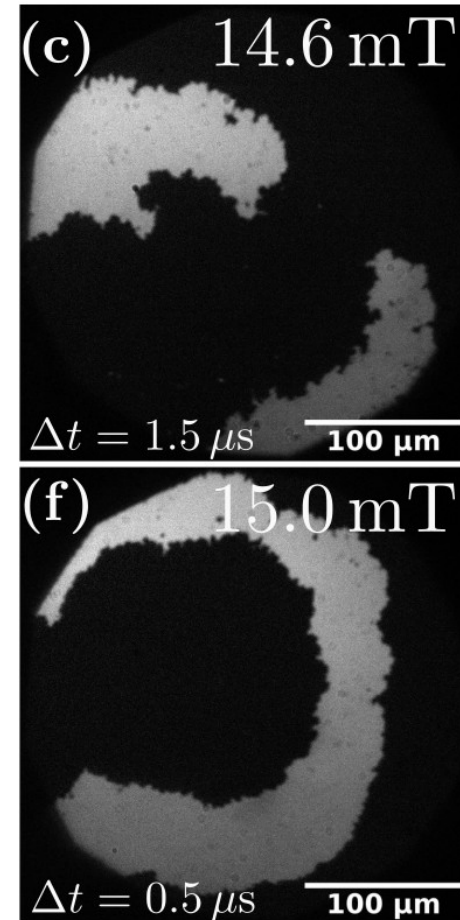
Athermal depinning transition below 70 K!

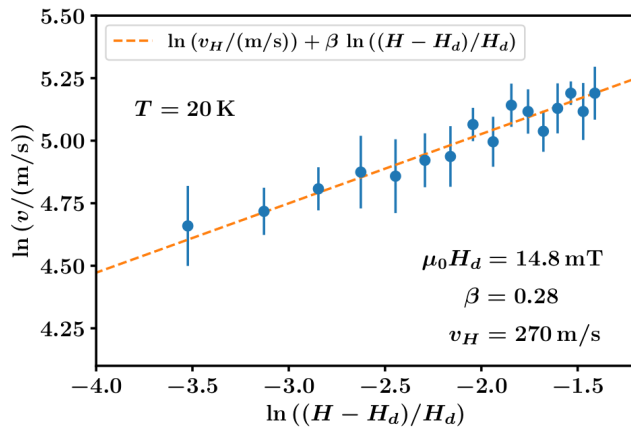
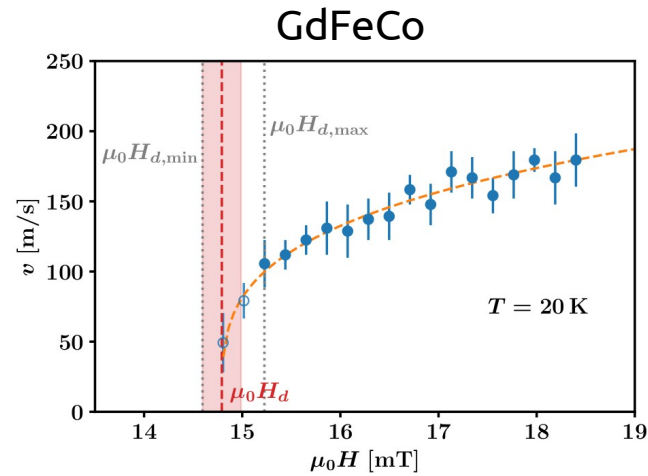


$$v(H, T = 0K) = v_H \left(\frac{H - H_d}{H_d} \right)^\beta$$

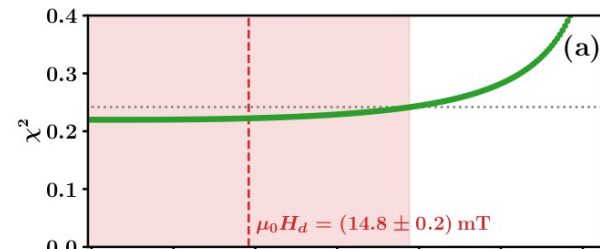


$$v(H, T = 0K) = v_H \left(\frac{H - H_d}{H_d} \right)^\beta$$

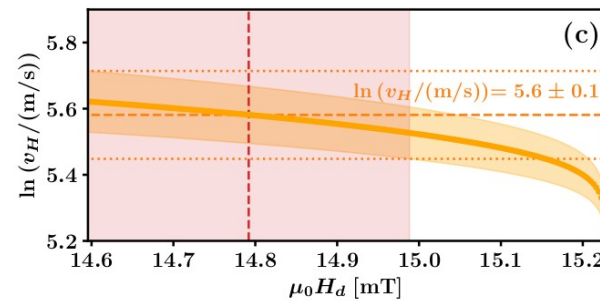
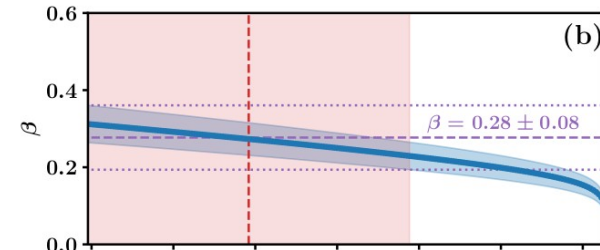


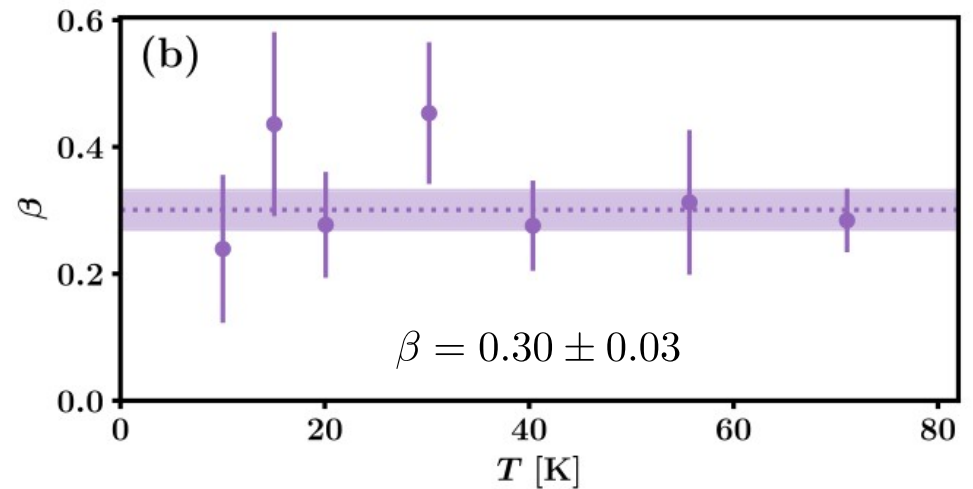
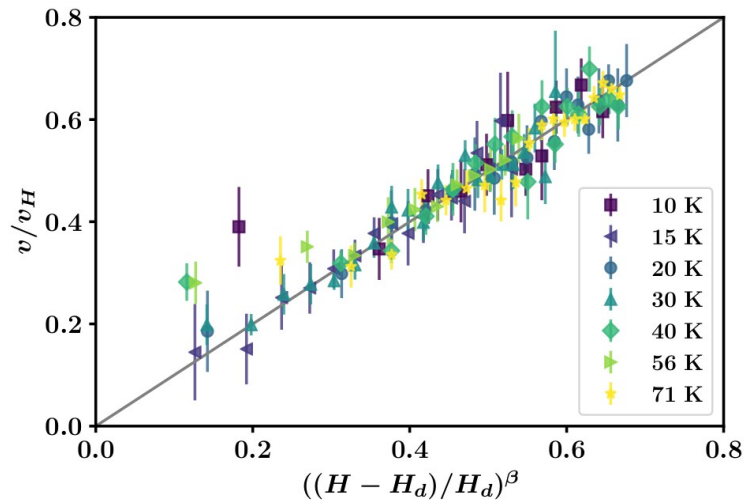


$$v(H, T = 0K) = v_H \left(\frac{H - H_d}{H_d} \right)^\beta$$



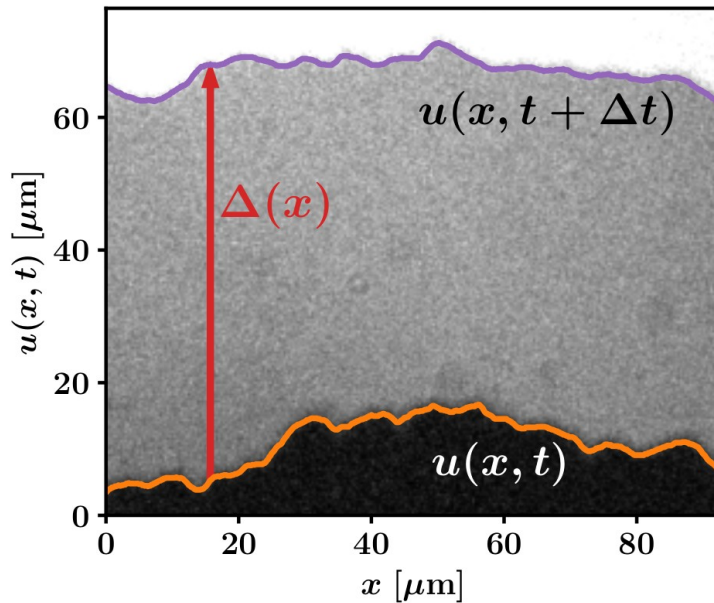
$1.1 \chi_{min}^2$





(Alternatively: fitting β as a single global parameter, independent of T , gives a consistent result $\beta = 0.33 \pm 0.04$)

GdFeCo

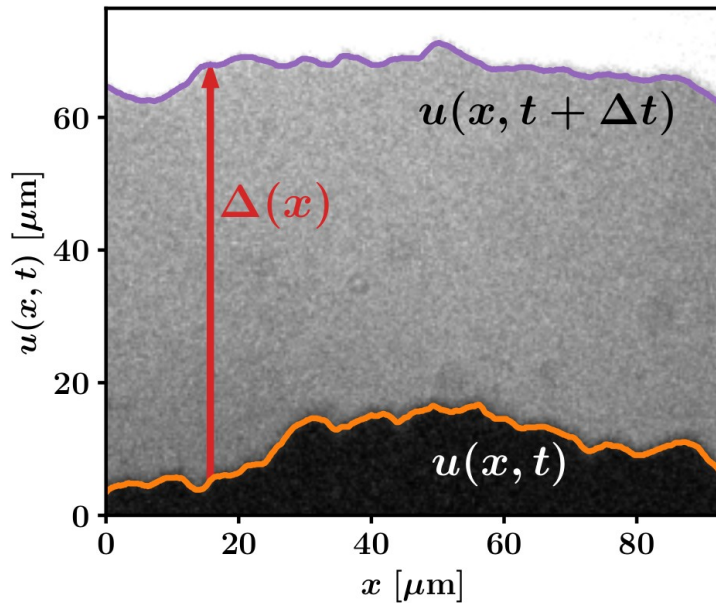


$$C_v(x) = \frac{1}{\Delta t^2} \sum [\Delta(x' + x) - \bar{\Delta}] [\Delta(x') - \bar{\Delta}]$$

$$\Delta = \frac{1}{N} \sum \Delta(x)$$

$$C_v(x = \xi) = \frac{1}{2} C_v(x = 0)$$

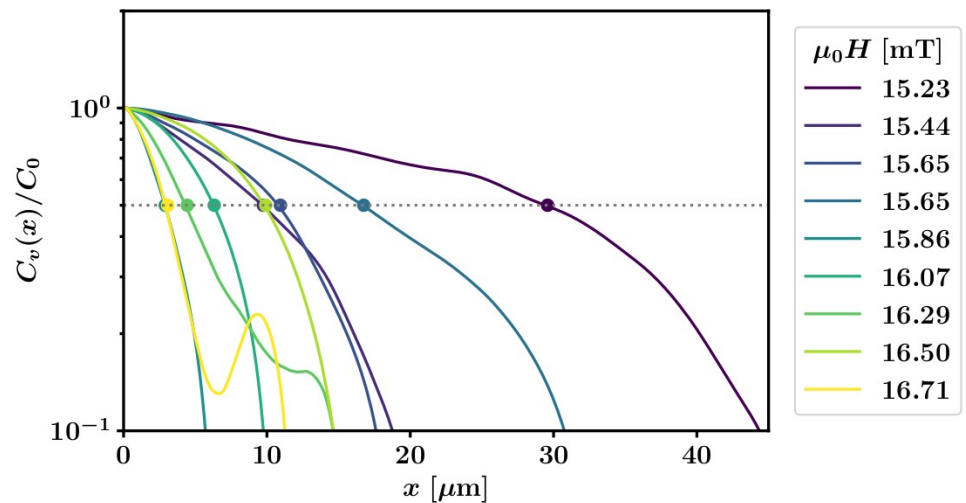
GdFeCo



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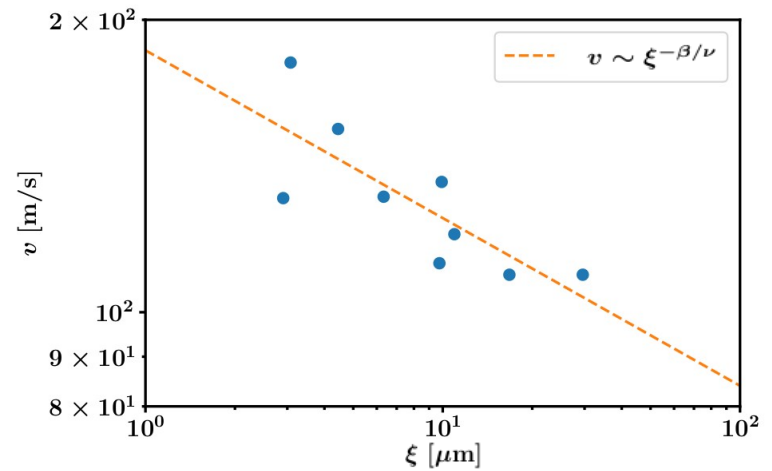
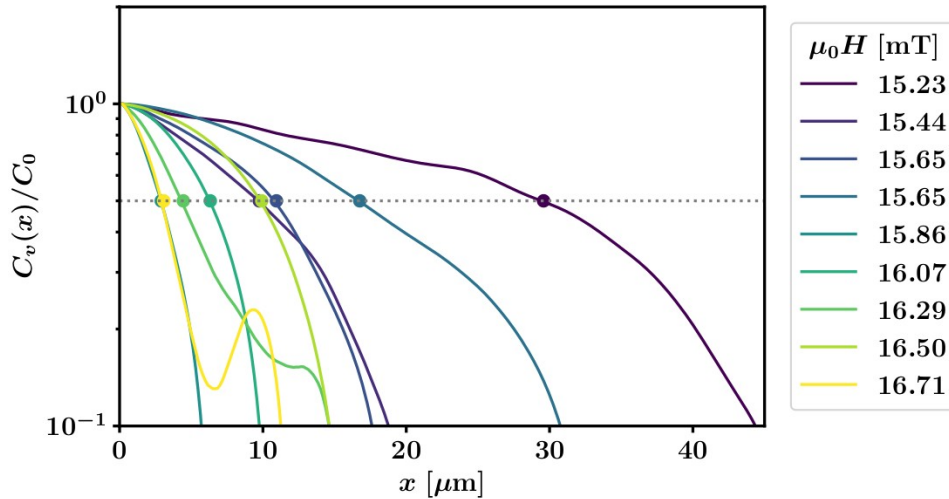
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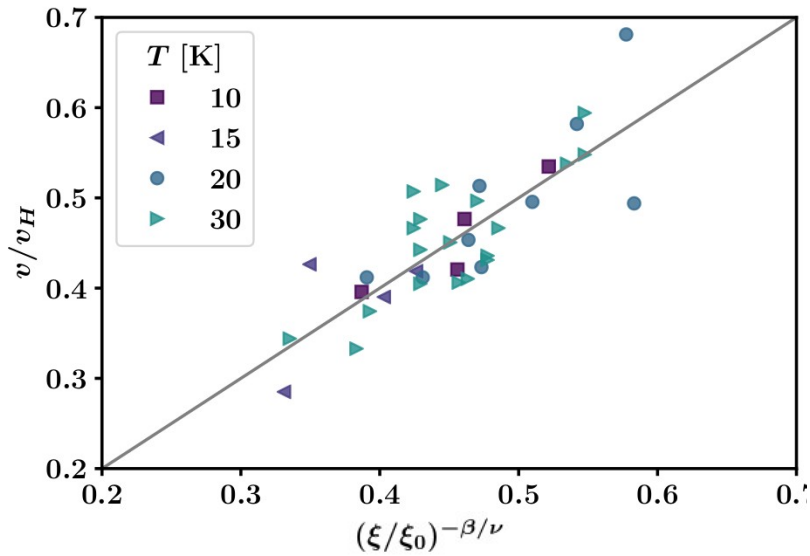
GdFeCo

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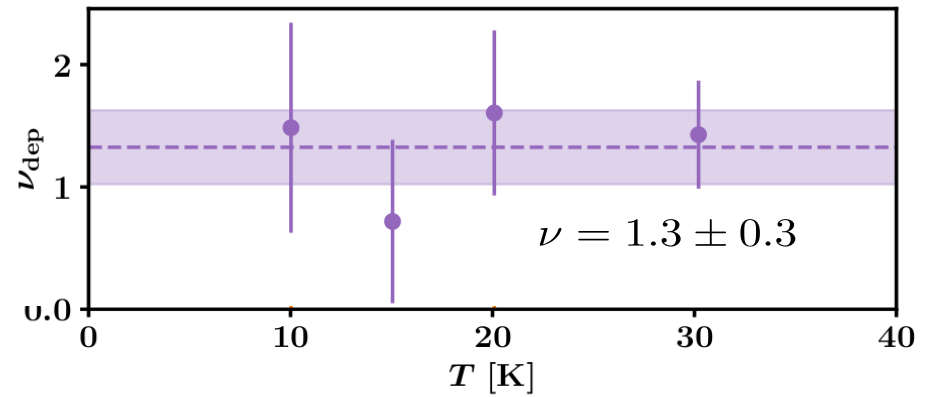


$$\left. \begin{aligned} \xi(H, T = 0K) &= \xi_0 \left(\frac{H - H_d}{H_d} \right)^{-\nu} \\ v(H, T = 0K) &= v_H \left(\frac{H - H_d}{H_d} \right)^{\beta} \end{aligned} \right\} v = v_H \left(\frac{\xi}{\xi_0} \right)^{-\beta/\nu}$$

The correlation length exponent



$$v = v_H \left(\frac{\xi}{\xi_0} \right)^{-\beta/\nu}$$



exponent	qEW	qKPZ	Measured
β	$0.245 \pm 0.006^*$ $0.33 \pm 0.02^\dagger$	$\sim 0.64\text{\S}\ddagger$	0.30 ± 0.03
ν	$1.333 \pm 0.007^*$	$\sim 1.73\ddagger$	1.3 ± 0.3
ψ	$0.15 \pm 0.01^{**}$?	$0.15 \pm 0.03^{***}$
ζ	$1.250 \pm 0.005^*$	$\sim 0.63\text{\S}$	1.2 ± 0.2
z	$1.433 \pm 0.007^*$	$\sim 1\ddagger$	1.5 ± 0.2
τ	$1.11 \pm 0.04\blacklozenge$	$\sim 1.26\text{\S}\ddagger$	1.11 ± 0.07

* Ferrero, Bustingorry, Kolton, PRE (2013)

† Duemmer, Krauth, PRE (2005)

** Bustingorry, Kolton, Giamarchi, EPL (2008)

*** Gorchon, Bustingorry, Ferré, Jeudy, Kolton, Giamarchi, PRL (2014)

\S Rosso, Hartmann, Krauth, PRE (2003)

\ddagger Tang, Kardar, Dhar, PRL (1995)

\blacklozenge Ferrero, Foini, Giamarchi, Kolton, Rosso, PRL (2017)

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$$B(r) = \langle [u(x+r) - u(x)]^2 \rangle = B_0 \left(\frac{r}{r_0} \right)^{2\zeta}$$

$$\ell(t) \sim t^{-1/z}$$

$$P(S) \sim S^{-\tau}$$

$$\nu = \frac{1}{2 - \zeta}$$

$$\beta = \nu(z - \zeta)$$

$$\tau = 2 - \frac{2}{1 + \zeta}$$

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What we know...

DW motion is compatible with the EW universality class (... mostly)

What we partially know...

Relationship with micromagnetics, temperature dependent parameters.

Roughness exponents at different scales (multiple exponents, negative KPZ?).

What we don't...

Plasticity effects

Scaling relations with the thermal rounding exponent



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Ezequiel Ferrero



Vincent Jeudy



Alejandro Kolton



Javier Curiale



Sebastian Bustingorry

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