Dynamics of the KPZ interface in disordered media: theoretical and experimental studies

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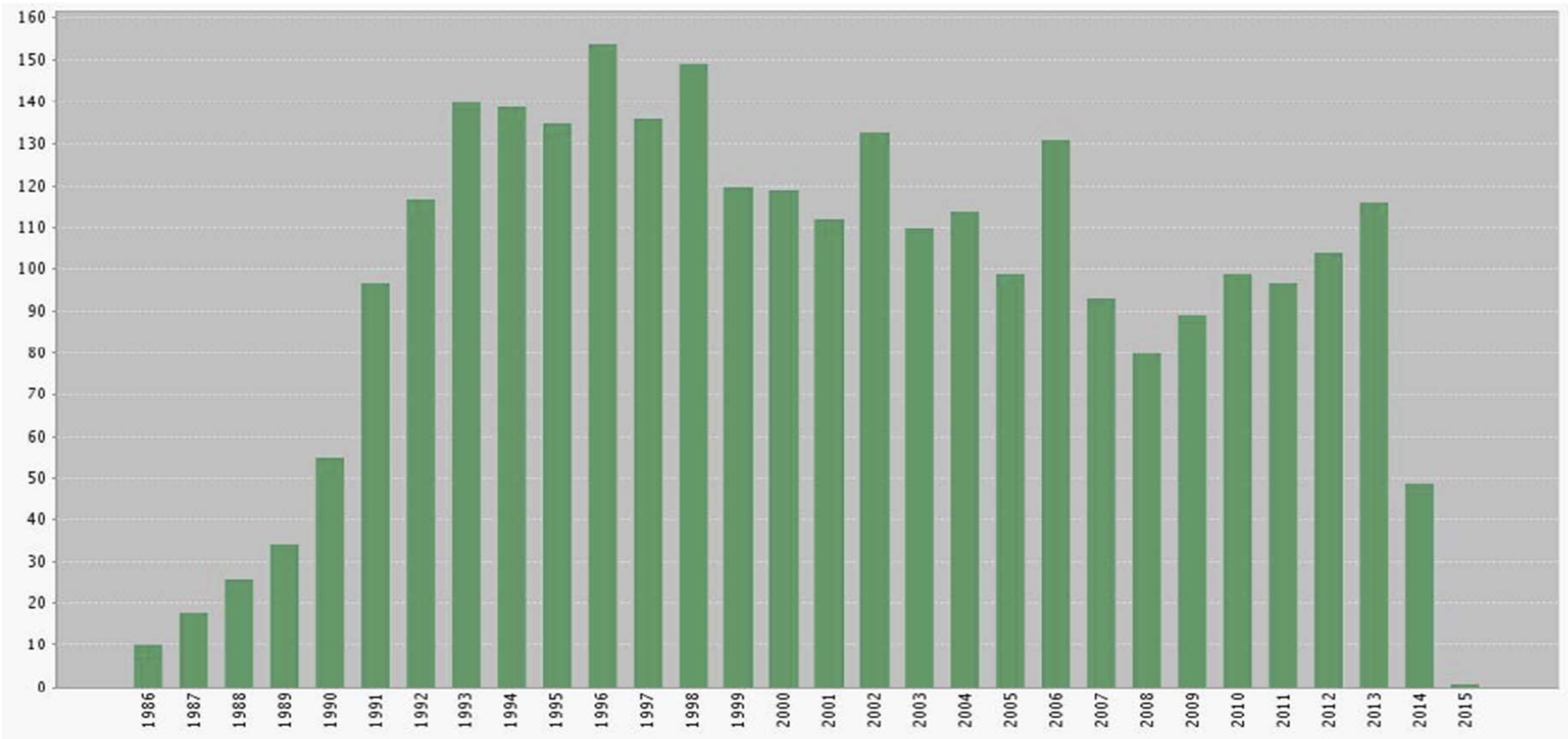
Interface fluctuations and KPZ universality class,

At YITP, Kyoto Japan, Aug 20th-23rd, 2014

The number of citations for the KPZ paper since 1986 = 3012 (total)



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- Doman wall motion in disordered media driven by electric current

KPZ equation with thermal noise

$$\frac{\partial h(x,t)}{\partial t} = V + \nu \frac{\partial^2 h}{\partial x^2} + \frac{\lambda}{2}\left(\frac{\partial h}{\partial x}\right)^2 + \eta(x,t) \qquad \left\langle (\Delta h_i)^2 \right\rangle^{1/2} \sim \begin{cases} t^{\beta} & t < L^z \\ L^{\alpha} & t > L^z \end{cases}$$

$\lambda \sim V$ α and β are invariant under $\lambda \leftrightarrow -\lambda$

Anisotropic KPZ equation

$$\frac{\partial h(x,y,t)}{\partial t} = \nu_x \frac{\partial^2 h}{\partial x^2} + \nu_y \frac{\partial^2 h}{\partial y^2} + \frac{\lambda_x}{2}\left(\frac{\partial h}{\partial x}\right)^2 + \frac{\lambda_y}{2}\left(\frac{\partial h}{\partial y}\right)^2 + \eta(x,y,t)$$

If $\lambda_x \lambda_y < 0$ AKPZ $\rightarrow$ EW universality class

Wolf, PRL (1991)

Stochastic model for the AKPZ class in weak coupling limit

- Three dimensional Toom model on a bcc lattice
- SoS model with avalanche process

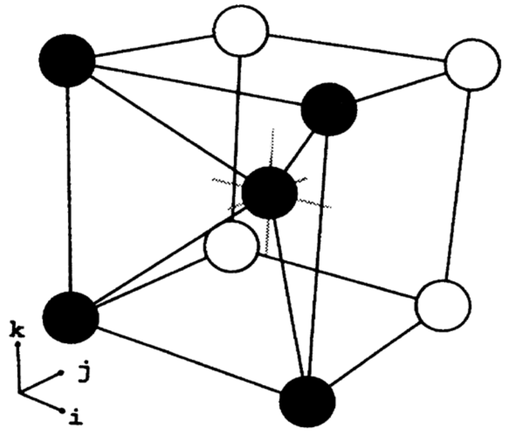
Derrida, Lebowitz, Speer, Spohn, PRL (1991)

$$\sigma_{i,j,k}(t+1) = \begin{cases} \text{majority rule} & \text{with prob} & 1-p-q \\ +1 & \text{with prob} & p \\ -1 & \text{with prob} & q \end{cases}$$

Majority rule

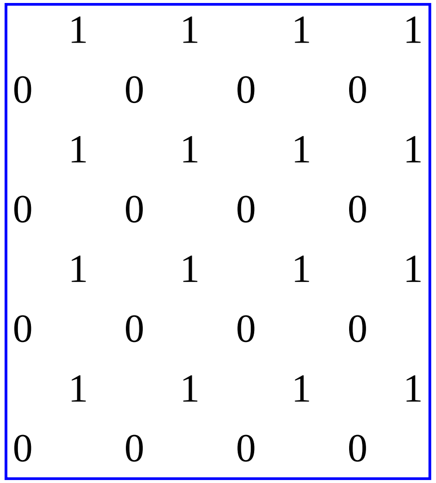
is applied according to

the five spins at black sites

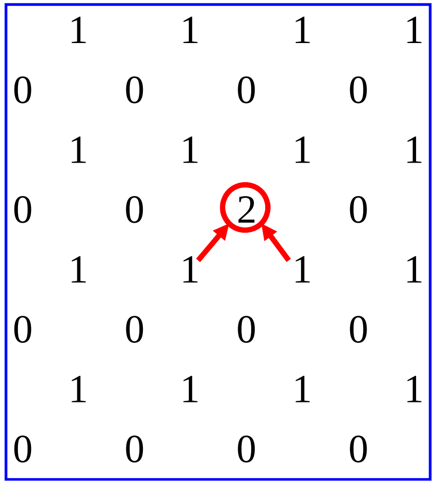


Jeong, BK and Kim, PRL (1993)

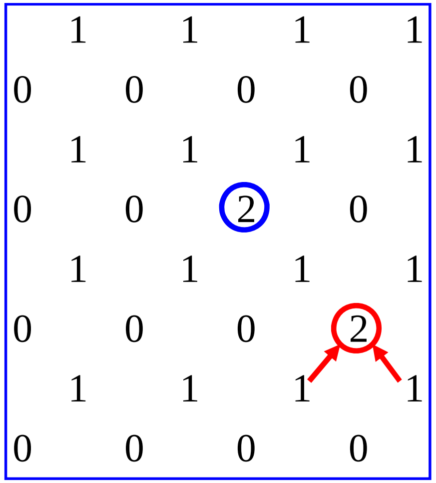
Solid-on-Solid model



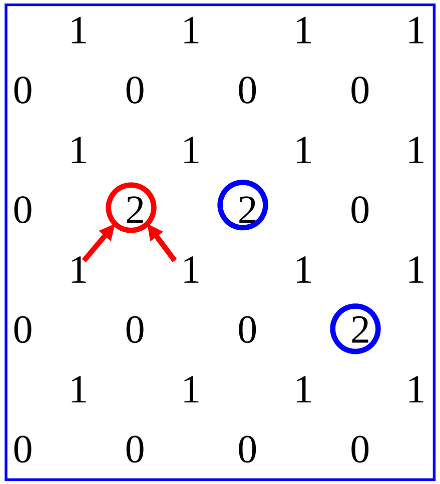
Initial state



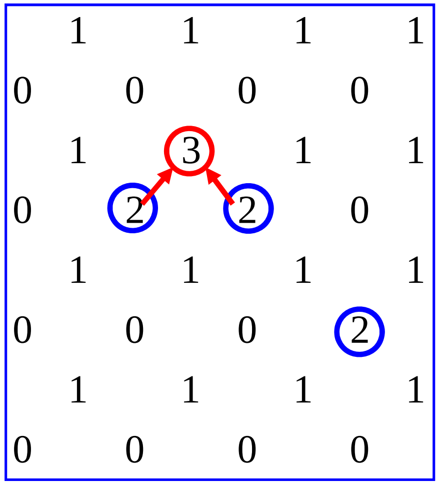
Random deposition under SOS



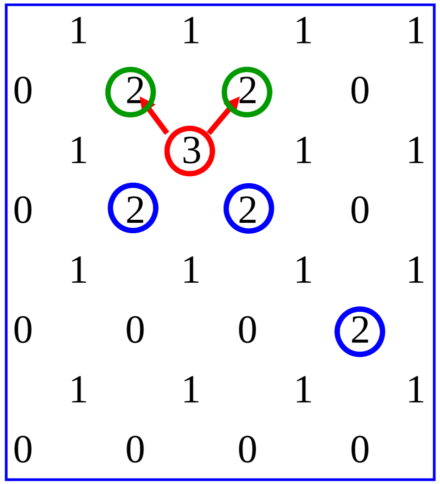
Random deposition under SOS



Random deposition under SOS



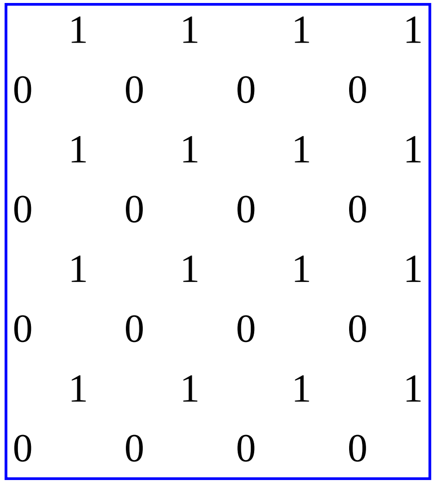
Random deposition under SOS



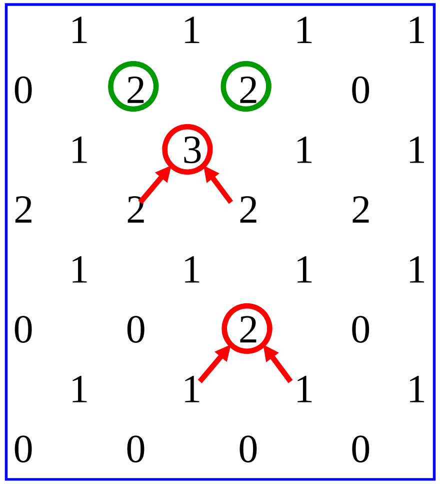
Avalanche for SOS

Signs of KPZ terms

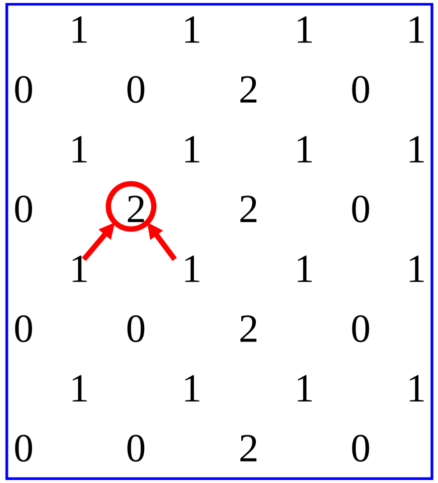
Purely deposition case p=0



Initial state



Tilted along j direction



Tilted along i direction

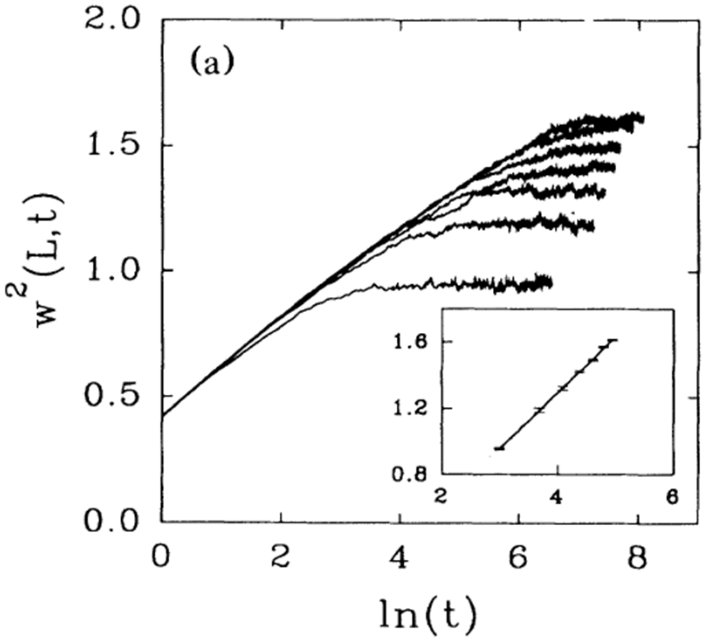
$$\langle \Delta h \rangle_0 = \frac{L^2}{2L^2} 2 = 1$$

$$\langle \Delta h \rangle_{\parallel} = \frac{L(L-1)}{2L^2} 2 + \frac{L}{2L^2} 6 = 1 + \frac{2}{L}$$

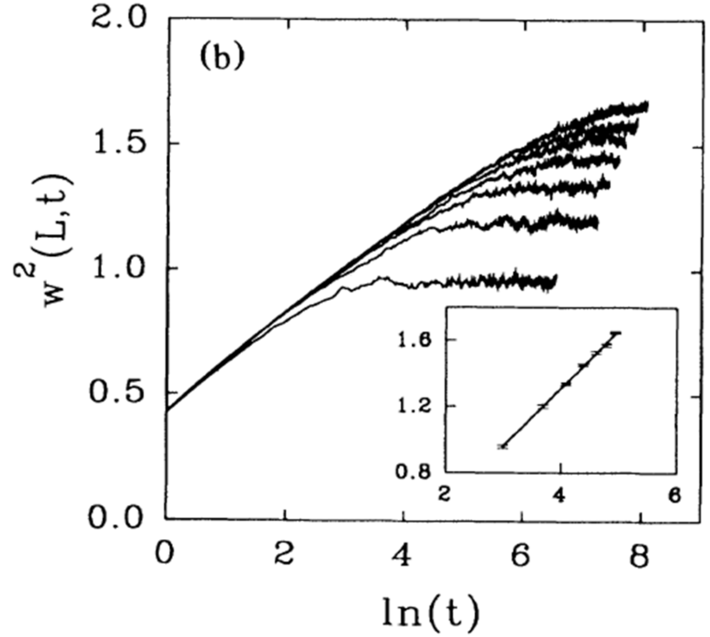
$$\langle \Delta h \rangle_{\perp} = \frac{L(L-1)}{2L^2} 2 = 1 - \frac{1}{L}$$

$$\langle \Delta h \rangle_{\parallel} > \langle \Delta h \rangle_0 \Rightarrow \lambda_y > 0$$

$$\langle \Delta h \rangle_{\perp} < \langle \Delta h \rangle_0 \Rightarrow \lambda_x < 0$$



Evaporation rate p=0.5



Evaporation rate p=0.3

EW universality class

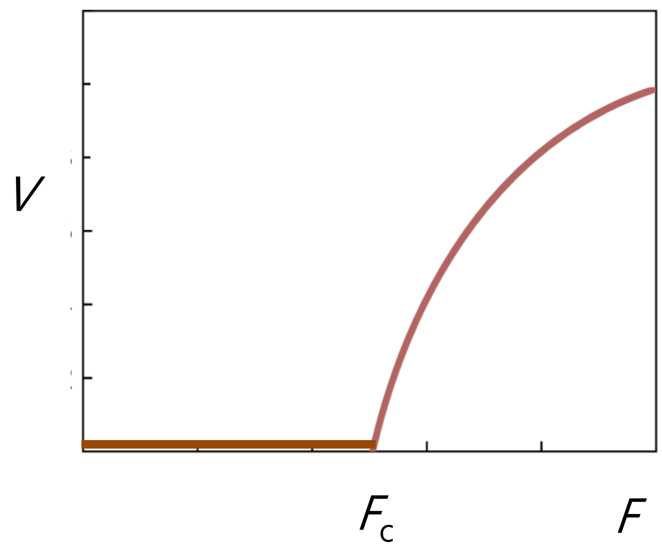
KPZ equation with quenched noise

$$\frac{\partial h(x,t)}{\partial t} = \nu \frac{\partial^2 h}{\partial x^2} + \frac{\lambda}{2}\left(\frac{\partial h}{\partial x}\right)^2 + F + \eta(x,h)$$

$$\langle \eta(x,h) \rangle = 0 \quad \langle \eta(x,h)\eta(x',h') \rangle = 2D\delta(x-x')\delta(h-h')$$

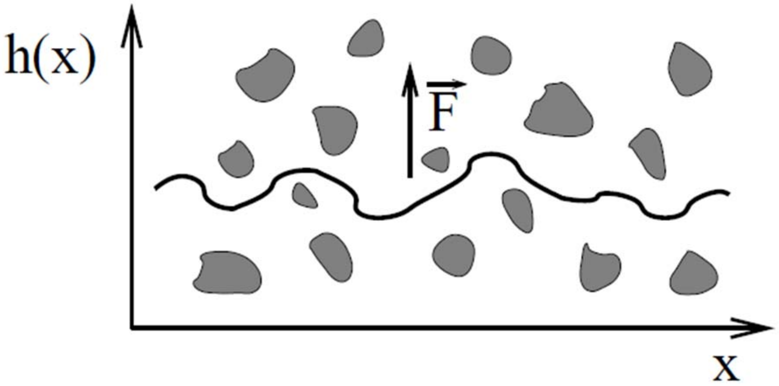
Pinning-depinning (PD) transition: When $\lambda > 0$

$$v(m=0) \sim (F-F_c)^{\theta}, \theta = \nu_{\parallel} - \nu_{\perp} \approx 0.64$$



Continuous transition

Surface roughness: $w \sim L^{\alpha} \quad (\alpha = \nu_{\perp}/\nu_{\parallel} \approx 0.633)$ Directed percolation class

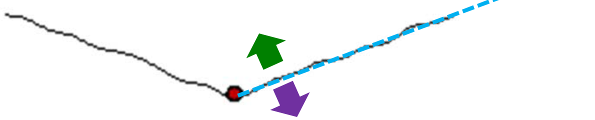


KPZ equation

$$\frac{\partial h(x,t)}{\partial t} = \nu \frac{\partial^2 h}{\partial x^2} + \frac{\lambda}{2}\left(\frac{\partial h}{\partial x}\right)^2 + F + \eta(x,h)$$

Positive λ (field) assists the interface motion

finite $|\partial h/\partial x|$



Negative λ (current) impedes the interface motion

Strong pinning effect to interface motion

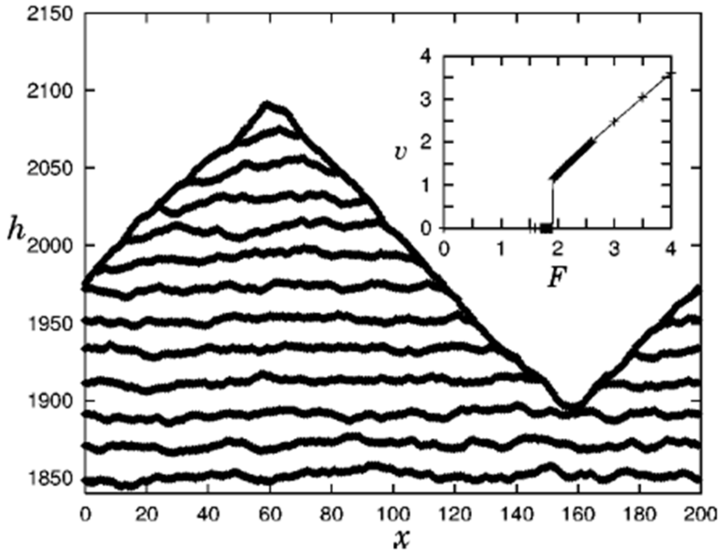
$$\frac{\partial h(x,t)}{\partial t} = \nu \frac{\partial^2 h}{\partial x^2} + \frac{\lambda}{2}\left(\frac{\partial h}{\partial x}\right)^2 + F + \eta(x,h)$$

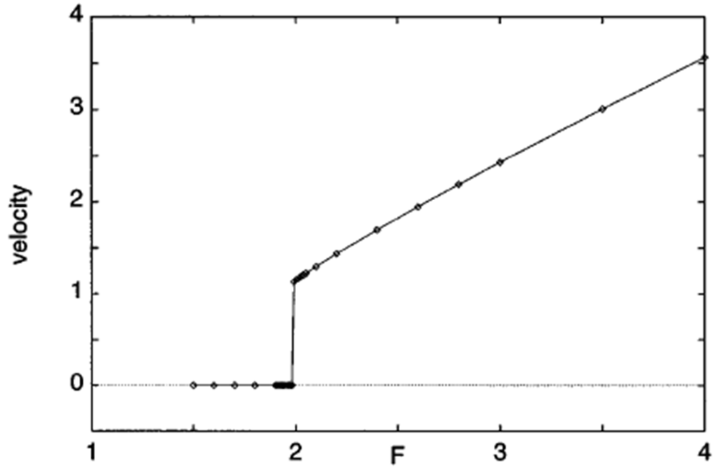
When $\lambda < 0$

Discontinuous PD transition

Facet formation

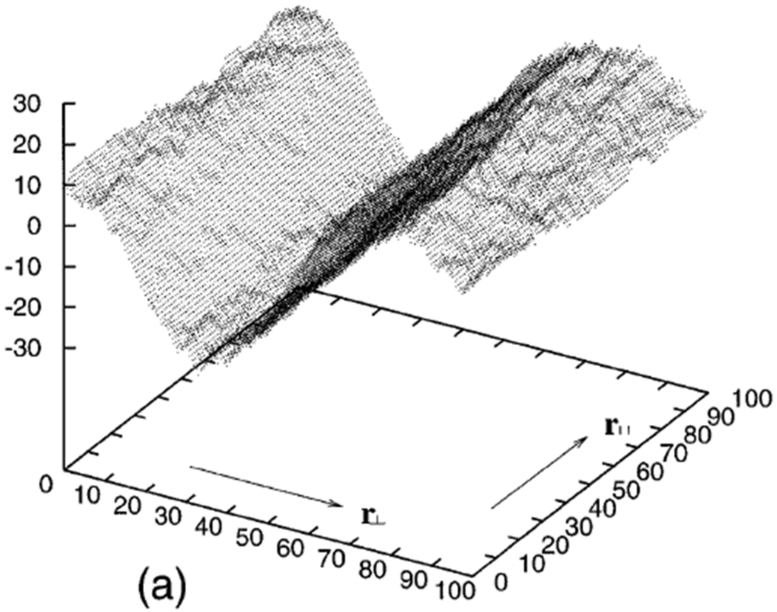
Jeong, BK and Kim,
PRL (1996), PRE (1999)

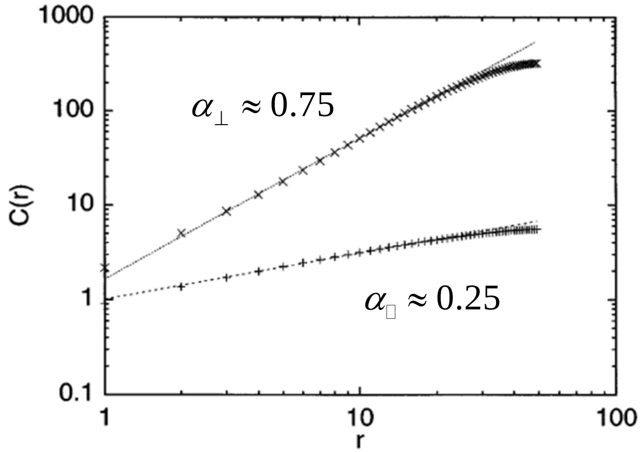


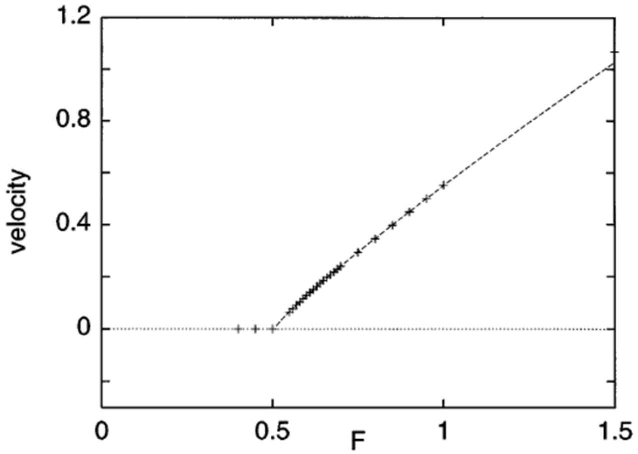


Anisotropic KPZ equation with quenched noise

$$\frac{\partial h(x,y,t)}{\partial t} = \nu_x \frac{\partial^2 h}{\partial x^2} + \nu_y \frac{\partial^2 h}{\partial y^2} + \frac{\lambda_x}{2}\left(\frac{\partial h}{\partial x}\right)^2 + \frac{\lambda_y}{2}\left(\frac{\partial h}{\partial y}\right)^2 + F + \eta(x,y,h)$$







Jeong, BK, Kim, PRL (1996)

Conclusion

Theory part

- Anisotropic KPZ equation with thermal noise in 2+1 dimensions: in weak coupling limit
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Experiment part

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