Rice and vortex matter in superconductors are similar granular systems

Rinke J. Wijngaarden
Christoph Aegerter
Marco Welling
Radboud Günther

vrije Universiteit amsterdam
Vrije Universiteit – Amsterdam – Pays Bas

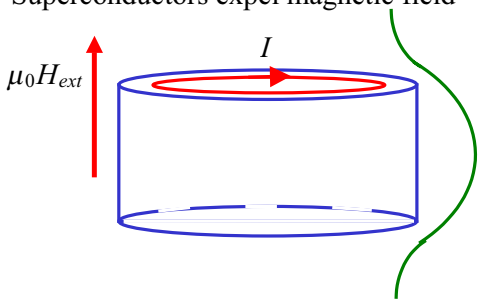
Carcassonne 25 September 2002

Overview

- Roughening of flux-scapes
- Roughening of rice piles
- Analysis and discussion

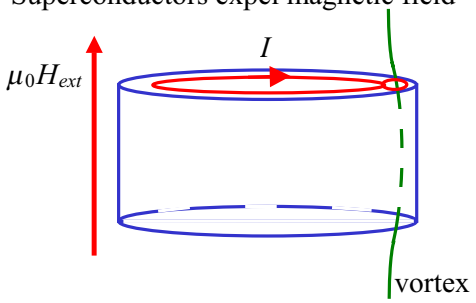
Brief intro superconductors: 1

Superconductors expel magnetic field



Brief intro superconductors: 1

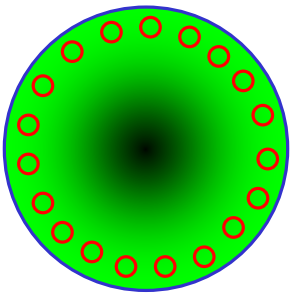
Superconductors expel magnetic field



Brief intro superconductors: 2

At high fields: fieldlines penetrate the sc through 'vortices'

Vortices are pinned

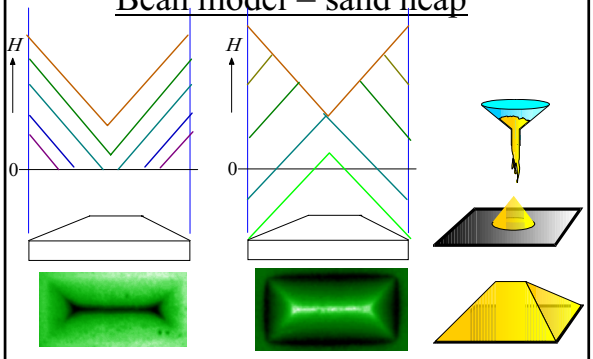


De Gennes' sand

The state thus realized is called the *critical state*, and was first described by Bean. We can get some physical feeling for this critical state by thinking of a sand hill. If the slope of the sand hill exceeds some critical value, the sand starts flowing downwards (avalanche).

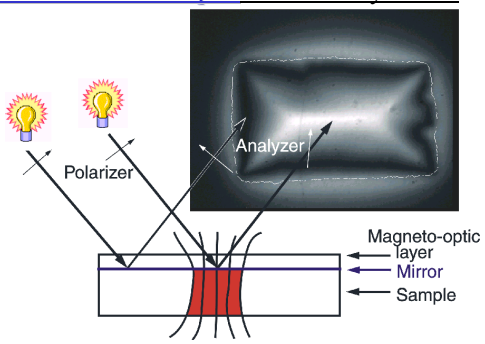
P.G. de Gennes, *Superconductivity of Metals and alloys*, section 3-3

Bean model = sand heap



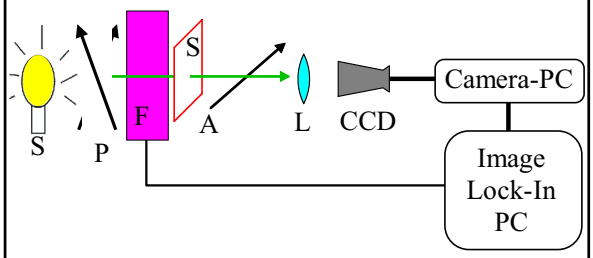
vortex density pile height

Experimental technique: the Faraday effect



$I = I_0 \sin^2\phi \simeq I_0\phi^2$

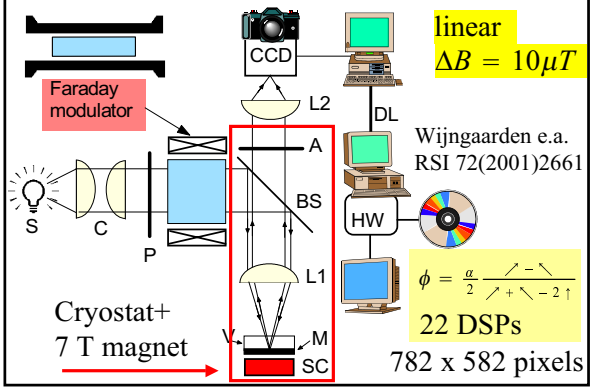
Magneto-optic image lock-in amplifier



$$\phi = \frac{\alpha}{2}\frac{\nearrow - \nwarrow}{\nearrow + \nwarrow - 2\uparrow}$$

Wijngaarden e.a. RSI 72(2001)2661

Magneto-optic Image Lock-in Amplifier



linear $\Delta B = 10\mu T$

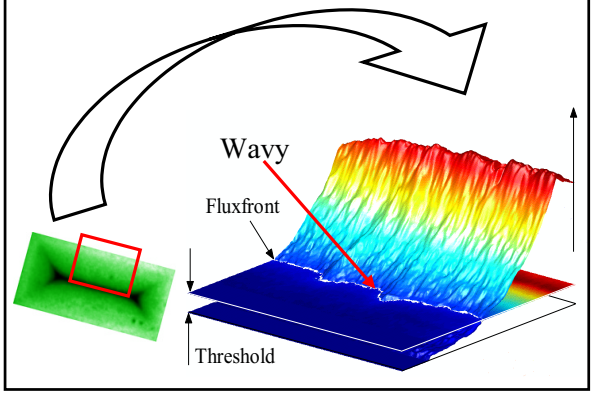
Wijngaarden e.a. RSI 72(2001)2661

$\phi = \frac{\alpha}{2}\frac{\nearrow - \nwarrow}{\nearrow + \nwarrow - 2\uparrow}$

22 DSPs

782 x 582 pixels

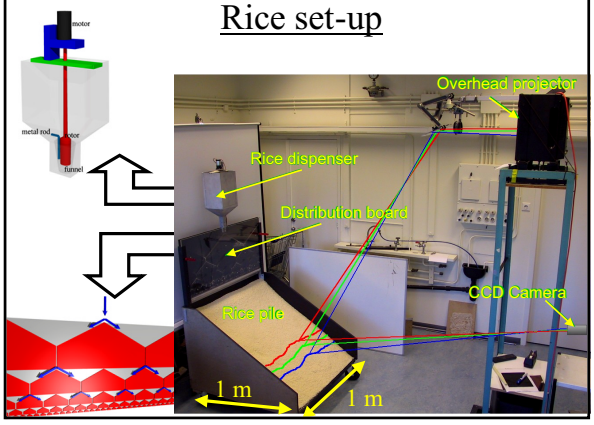
Roughening of vortex-sand or flux-scapes



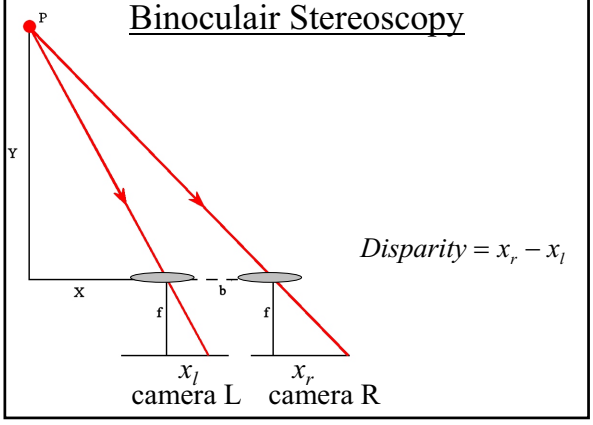
Overview

- Roughening of flux-scapes
- Roughening of rice piles
- Analysis and discussion

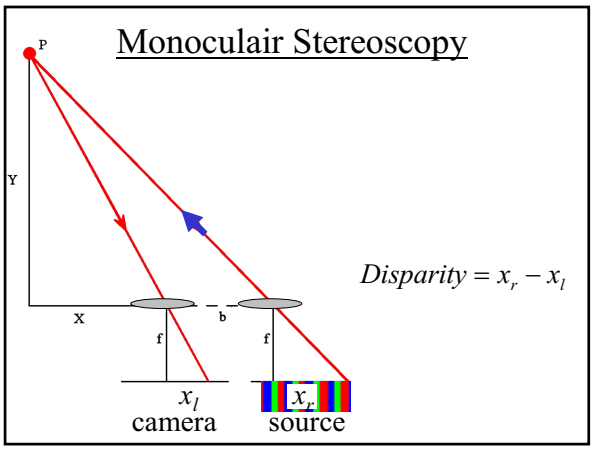
Rice set-up

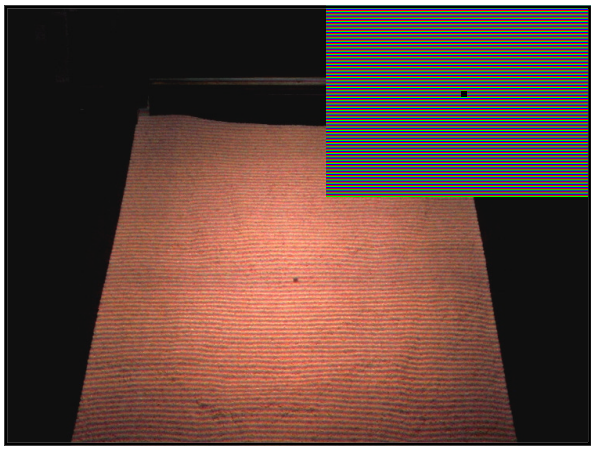


Binoculair Stereoscopy

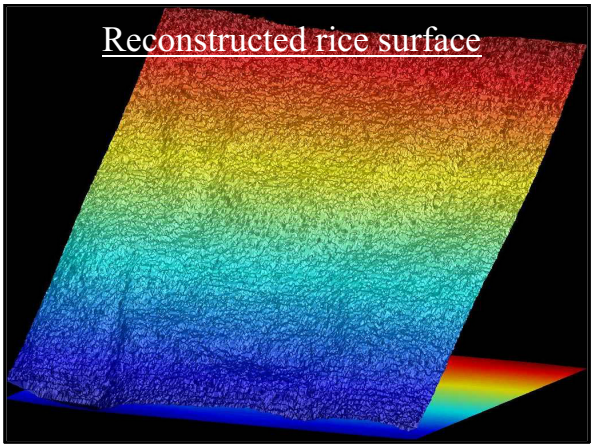


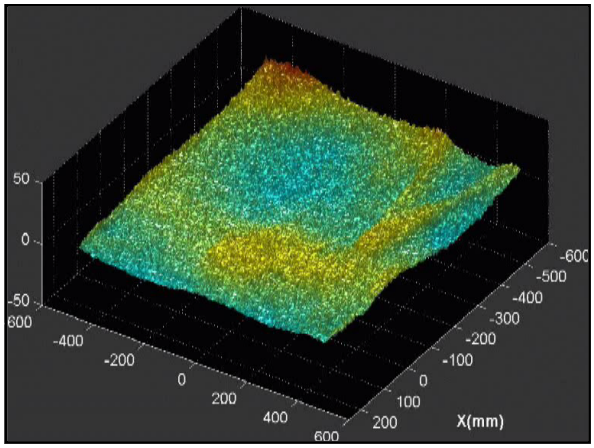
Monoculair Stereoscopy



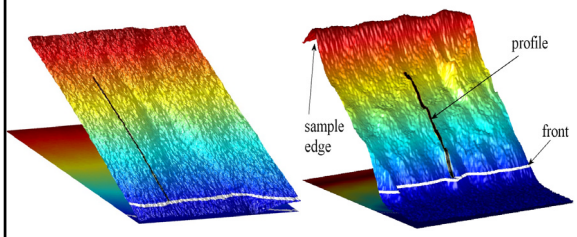


Reconstructed rice surface





Rice-piles and vortex-scapes

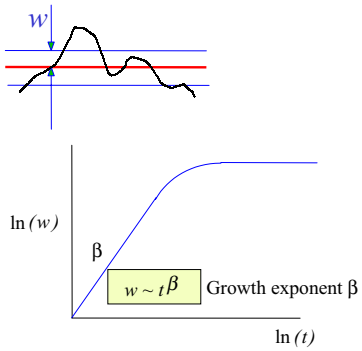


rice superconductor

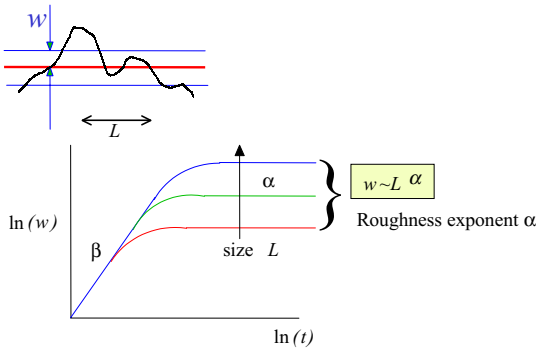
Overview

- Roughening of flux-scapes
- Roughening of rice piles
- Analysis and discussion

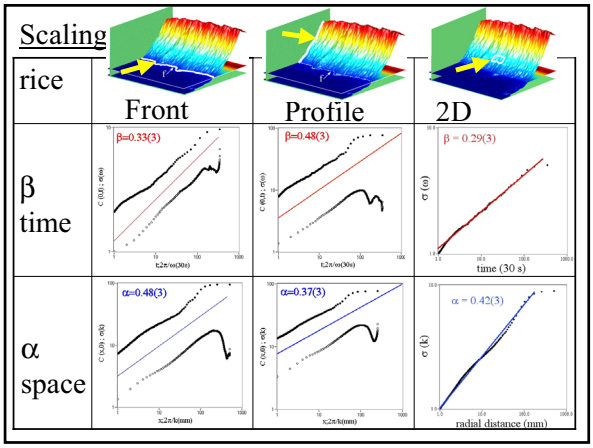
Growth exponent β



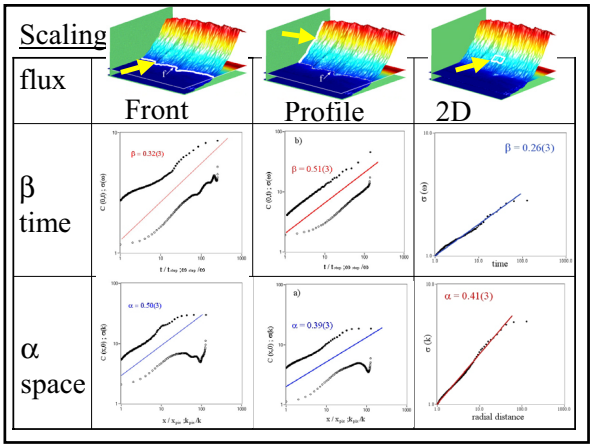
Roughness exponent α



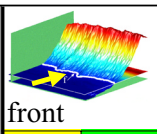
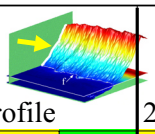
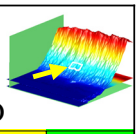
Scaling



Scaling



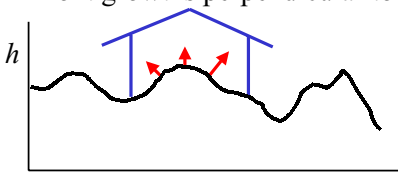
Exponents

	front		profile		2D	
	rice	**flux**	**rice**	**flux**	**rice**	**flux**
β time	0.33_3	0.33_5	0.48_3	0.50_5	0.29_3	0.26_3
α space	0.48_3	0.50_5	0.37_3	0.38_5	0.42_3	0.41_3

Kardar Parisi Zhang equation

A front growths perpendicular to its interface

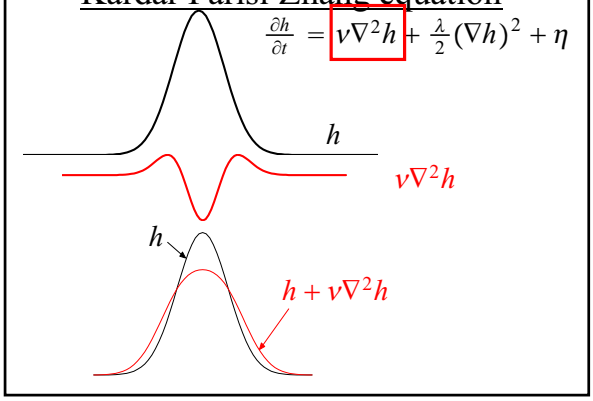


$$\frac{\partial h}{\partial t} = \nu\nabla^2 h + \frac{\lambda}{2}(\nabla h)^2 + \eta$$

diffusion non-linear noise

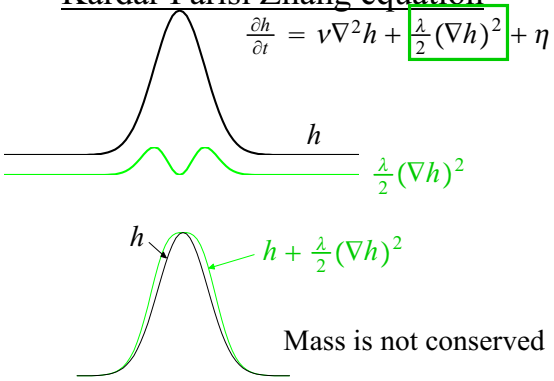
Kardar Parisi Zhang equation

$$\frac{\partial h}{\partial t} = \nu\nabla^2 h + \frac{\lambda}{2}(\nabla h)^2 + \eta$$



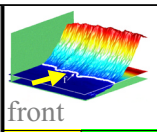
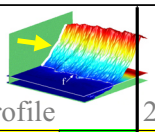
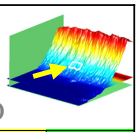
Kardar Parisi Zhang equation

$$\frac{\partial h}{\partial t} = \nu\nabla^2 h + \frac{\lambda}{2}(\nabla h)^2 + \eta$$



Mass is not conserved

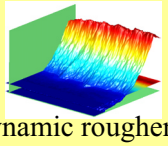
Exponents: Experiment and KPZ eqn.

	front		profile		2D	
	rice	**flux**	**rice**	**flux**	**rice**	**flux**
β time	0.33_3 **0.33**	0.33_5 **0.33**	0.48_3 1.0(6)	0.50_5 -	0.29_3 **0.24**	0.26_3 **0.24**
α space	0.48_3 **0.5**	0.50_5 **0.5**	0.37_3 0.2(1)	0.38_5 -	0.42_3 **0.38**	0.41_3 **0.38**

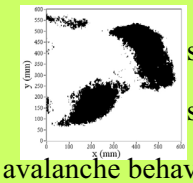
1D rice experiment Malthe Sørenssen ea.

Roughening and SOC



dynamic roughening

$\alpha,\ \beta$



size DF⇒ $\tau,\ D$

shape ⇒ d_B

$\alpha = D - d_B$

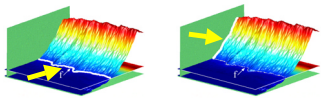
$\beta = \frac{D-d_B}{D(2-\tau)}$

avalanche behavior

Poster/Affiche: Christoph Aegerter

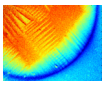
Conclusions

- Rice and superconductors are very similar
- Critical slope
- Growth en roughness exponent front
- Growth en roughness exponent profile
- Growth en roughness exponent surface
- Avalanche size distribution function

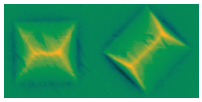


Outlook

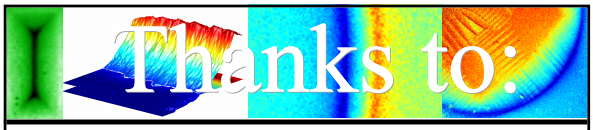
Use superconductors as a model granular system



- Fully overdamped
- Well defined interactions
- Indentical particles
- Control:



o Patterning: Anisotropy
o Temperature: ratio static/dynamic disorder
o Magnetic field: density



C.M. Aegerter
M. Welling
R. Günther
R. Surdeanu
J. Rector
B. Dam
R. Griessen

FOM

vrije Universiteit amsterdam