

*Where is the  
interesting physics  
in wind-blown sand?*

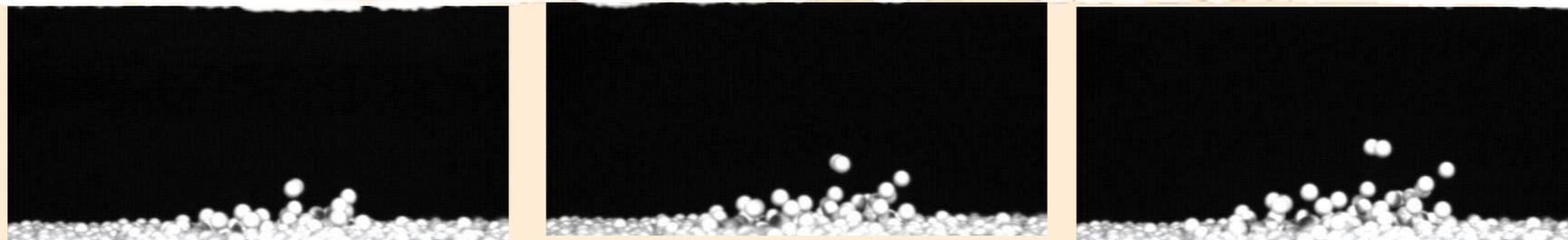
**Klaus Kroy (Uni Leipzig)**

**KITP 26/09/2013**

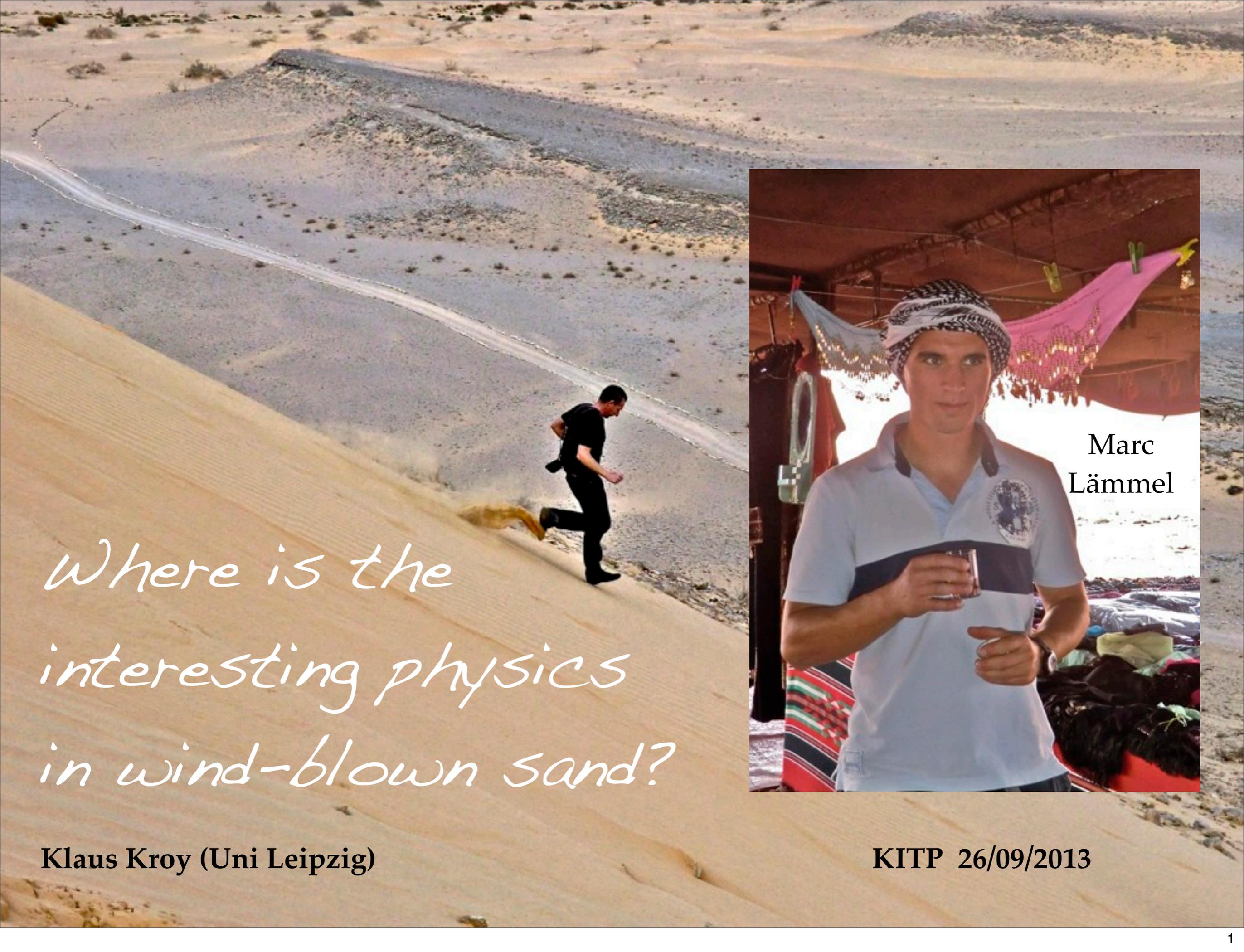
**Collision process between an incident bead and a three-dimensional granular packing**

Djaoued Beladjine, Madani Ammi, Luc Oger, and Alexandre Valance  
*Groupe Matière Condensée et Matériaux, UMR CNRS 6626, F-35042 Rennes cedex, France*

(Received 28 November 2006; published 14 June 2007)

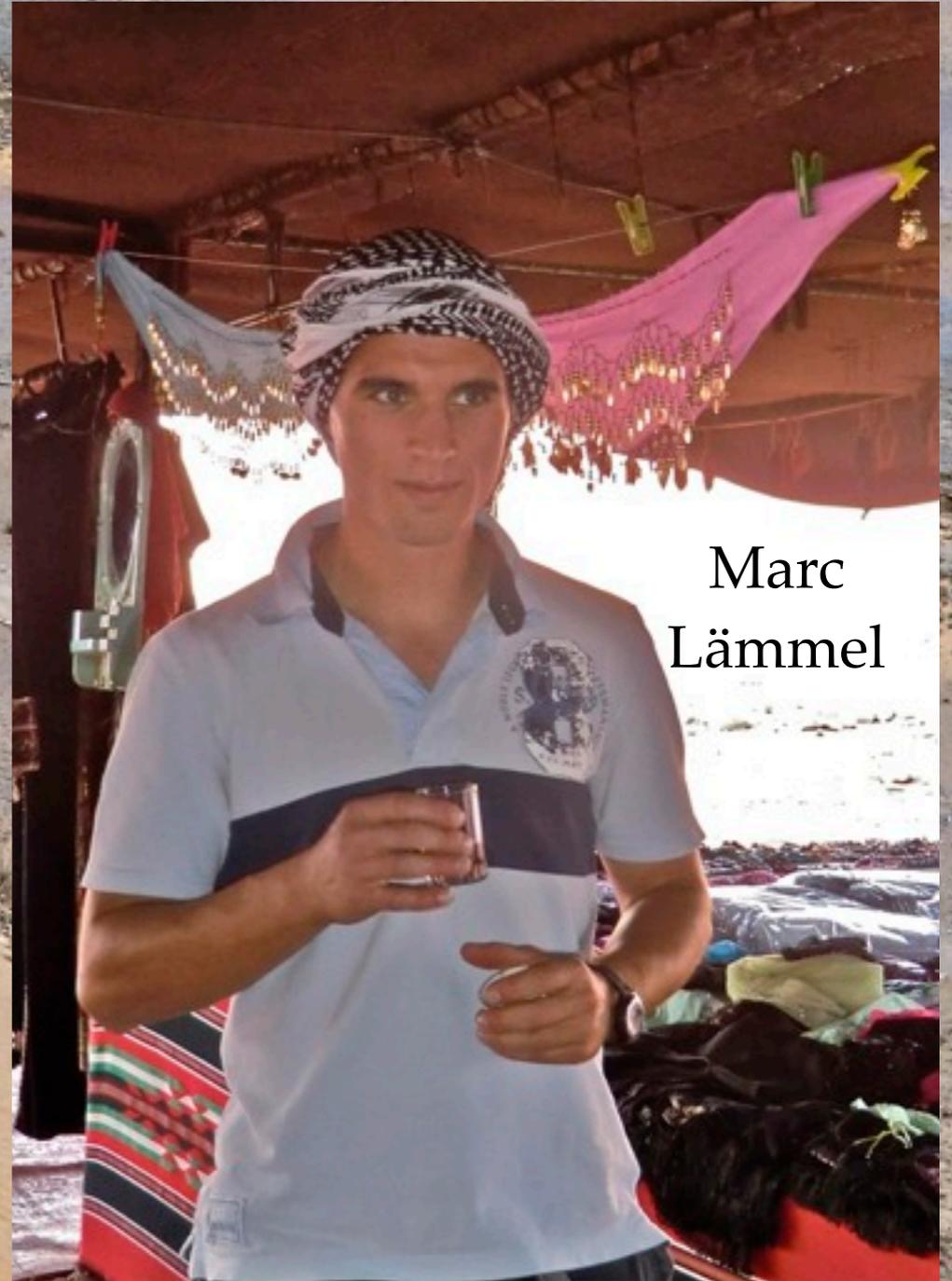


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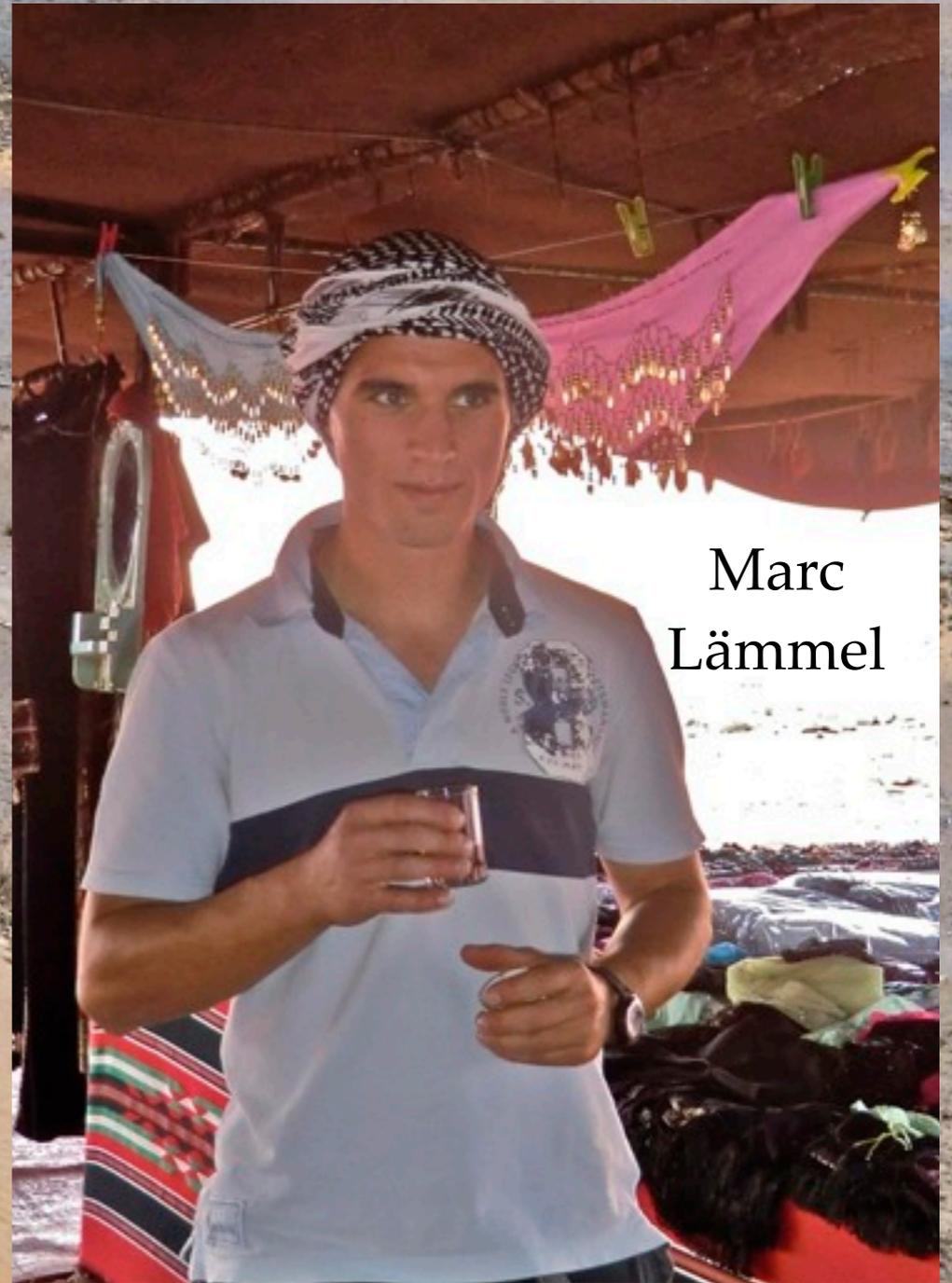
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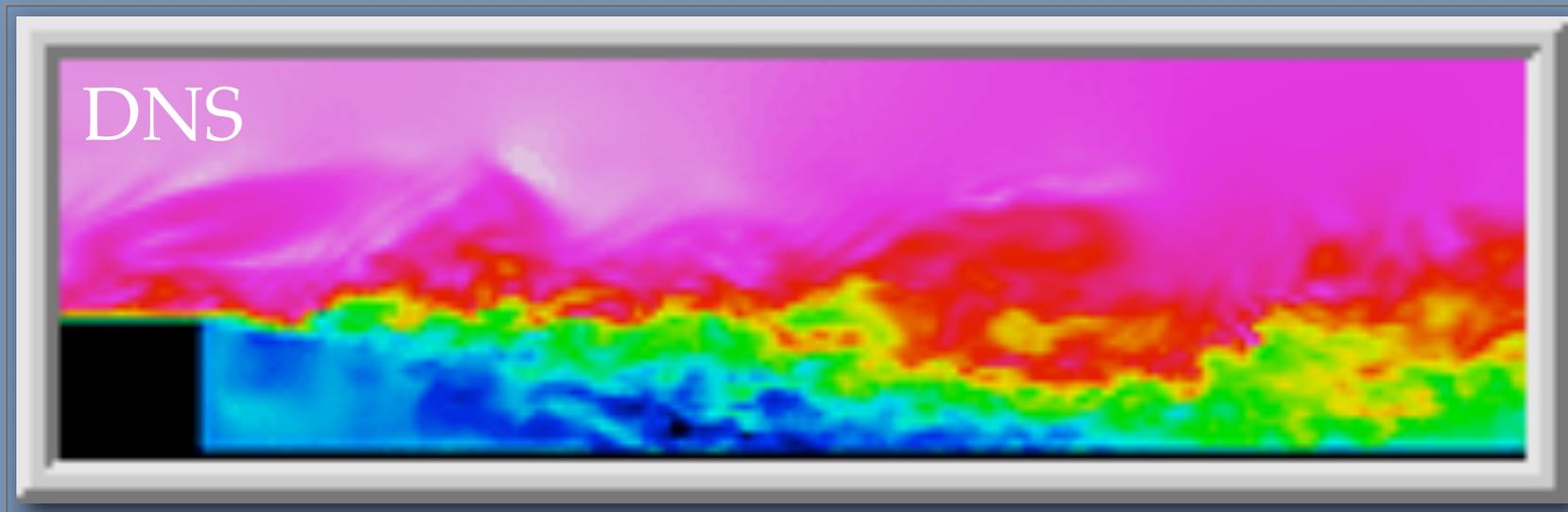
# Modeling Complexity



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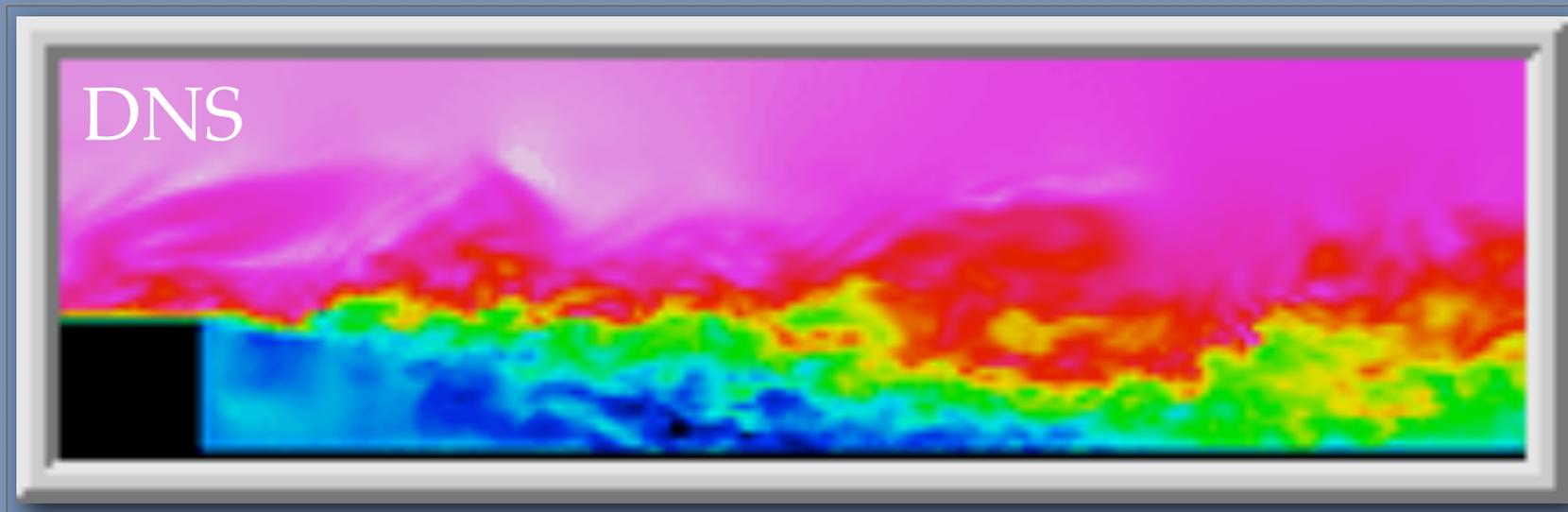


Stanford super-computer



Poor man's super-computer

# Modeling Complexity



Stanford super-computer

... is another person's  
problem



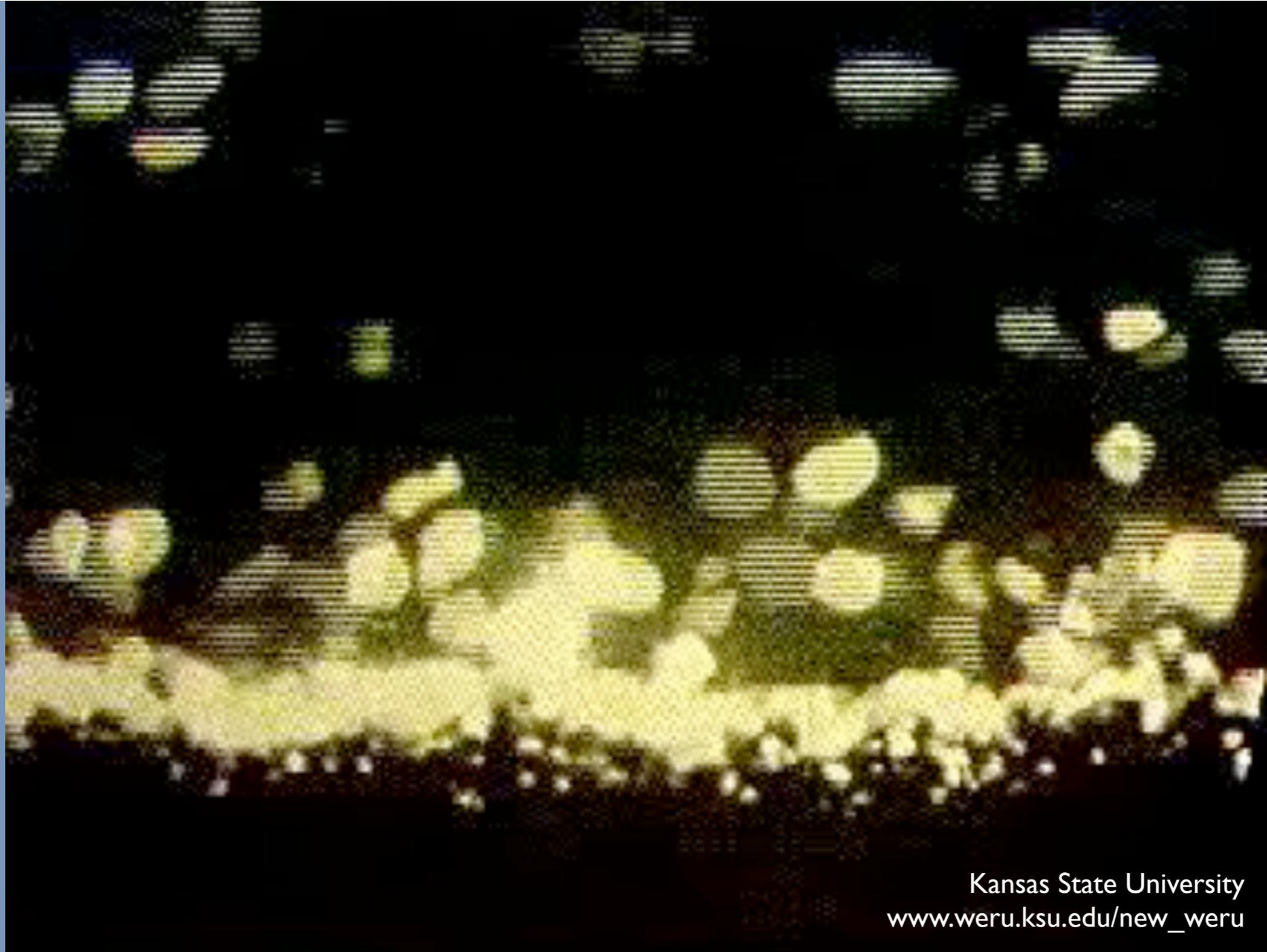
One person's solution ...

Poor man's super-computer

# Some Leapfrog Principles

- Conservation Laws Kill Details: **Hydrodynamics**
- Broken Symmetries Kill Boredom: **Dune Creation**
- Scale Invariance Restores Simplicity: **Dune Speed**
- Broken Scale Invariance Restores Details:  
**Dune Shape Transitions**
- Broken Symmetries & Magnified Noise: **Chance**

# Modeling Aeolian Sand Transport



Kansas State University  
[www.weru.ksu.edu/new\\_weru](http://www.weru.ksu.edu/new_weru)

# Hydrodynamic Models

PHYSICAL REVIEW E, VOLUME 64, 031305

## **Continuum saltation model for sand dunes**

Gerd Sauermann,<sup>1,2</sup> Klaus Kroy,<sup>1,\*</sup> and Hans J. Herrmann<sup>1,2</sup>

<sup>1</sup>*PMMH, Ecole Supérieure de Physique et Chimie Industrielles (ESPCI), 10, rue Vauquelin, 75231 Paris, Cedex 05, France*

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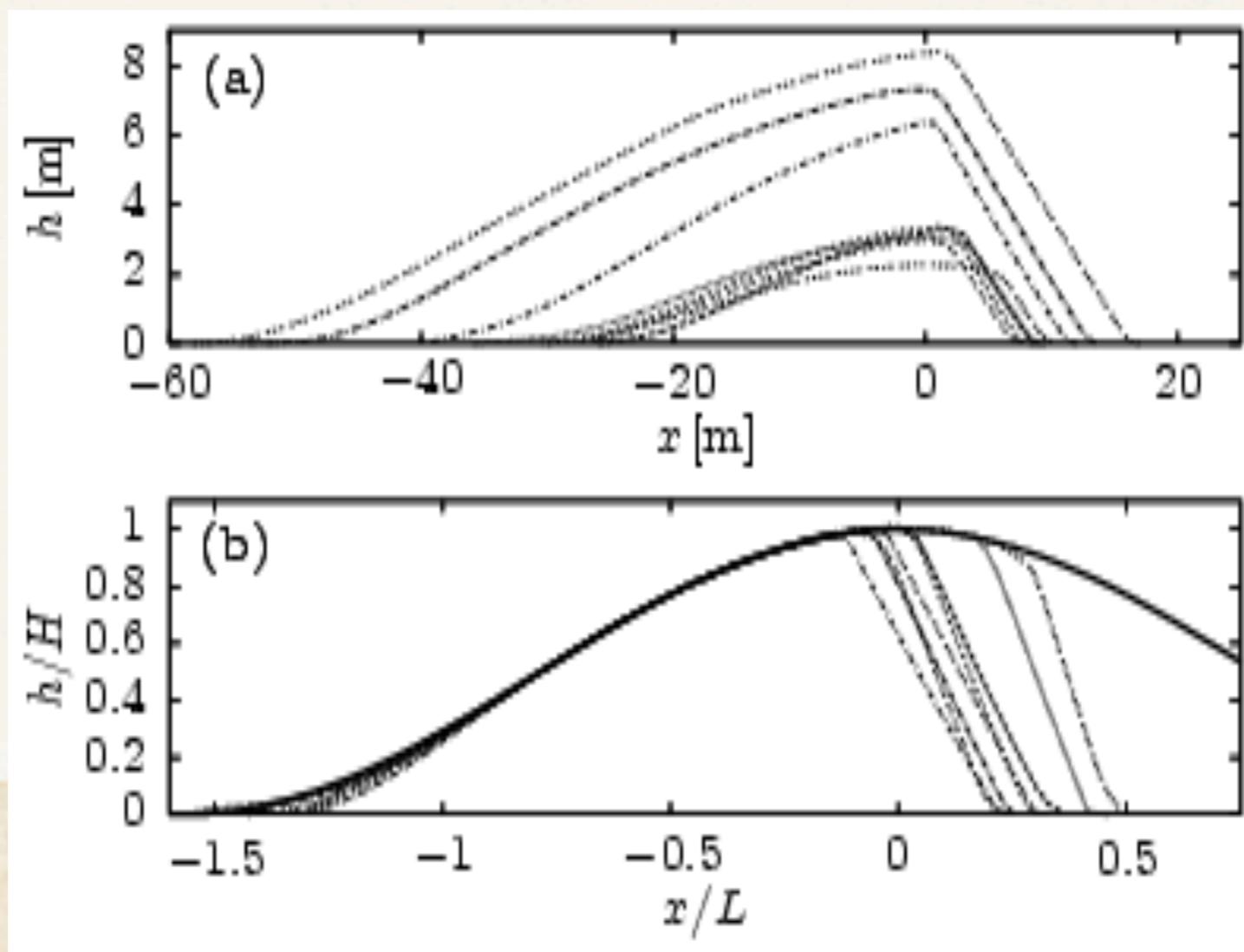
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# Why is the desert not flat?



VOLUME 88, NUMBER 5

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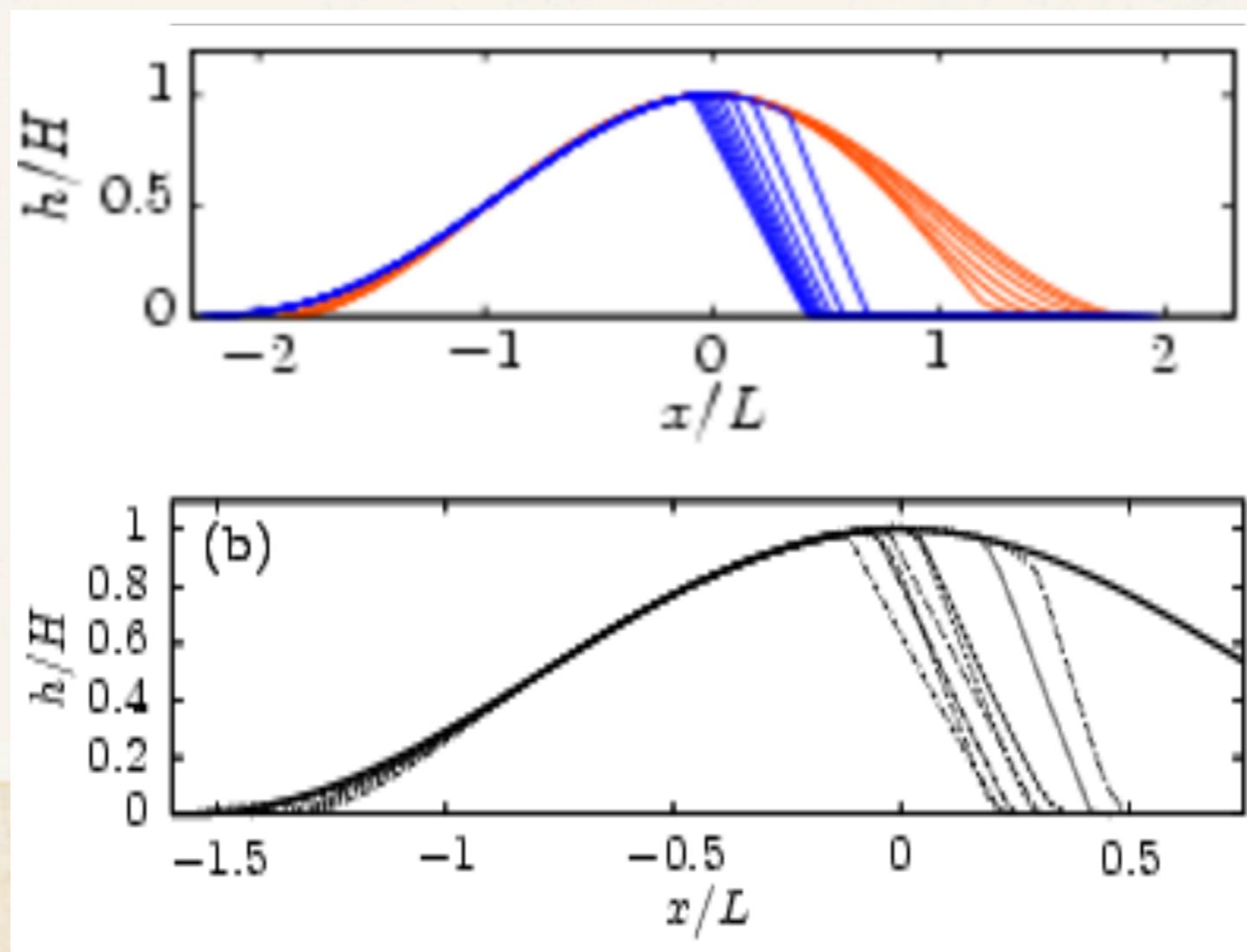
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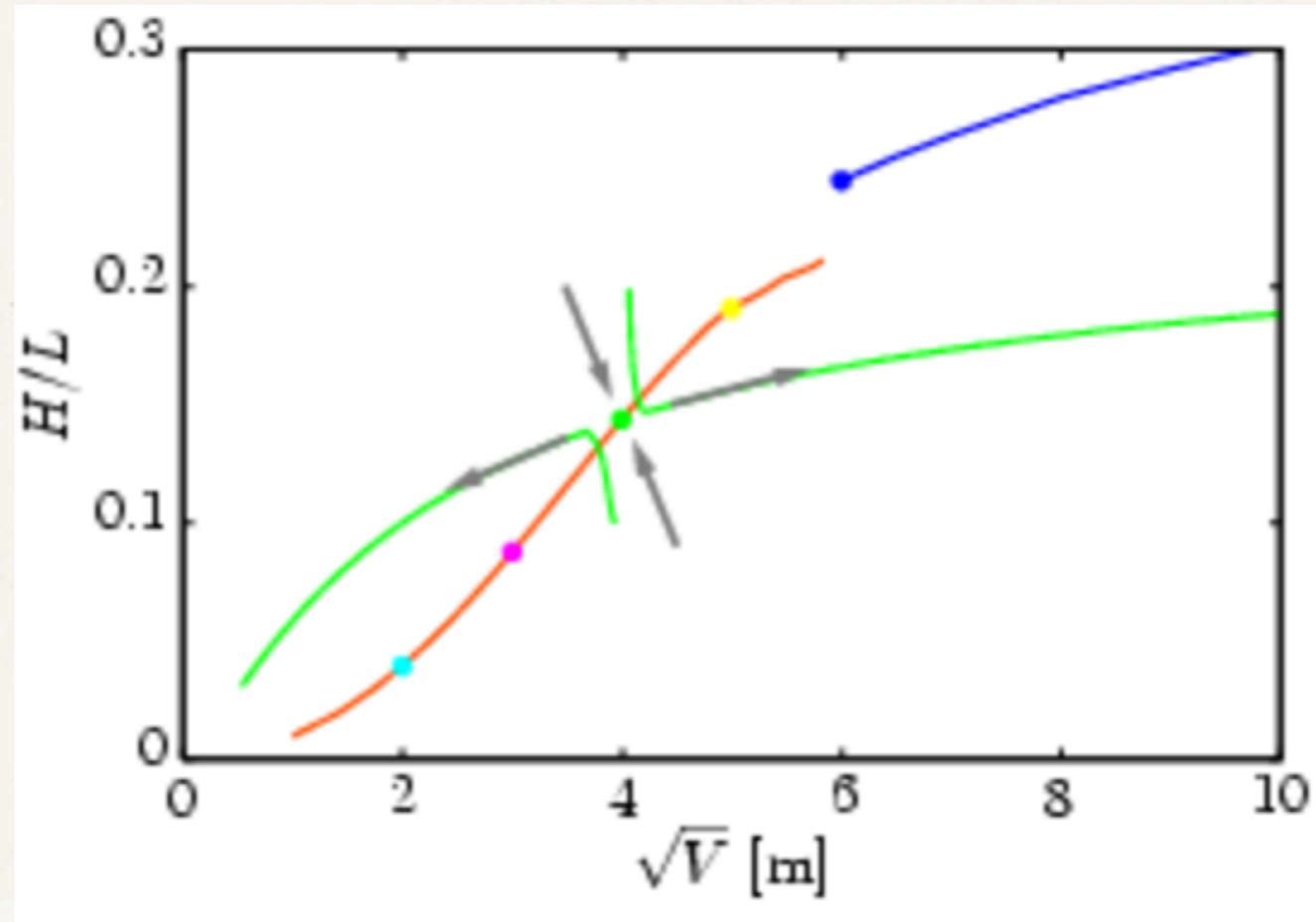
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# Dynamic Similarity Laws



PHYSICAL REVIEW E 77, 031302 (2008)

## Dynamic scaling of desert dunes

Sebastian Fischer

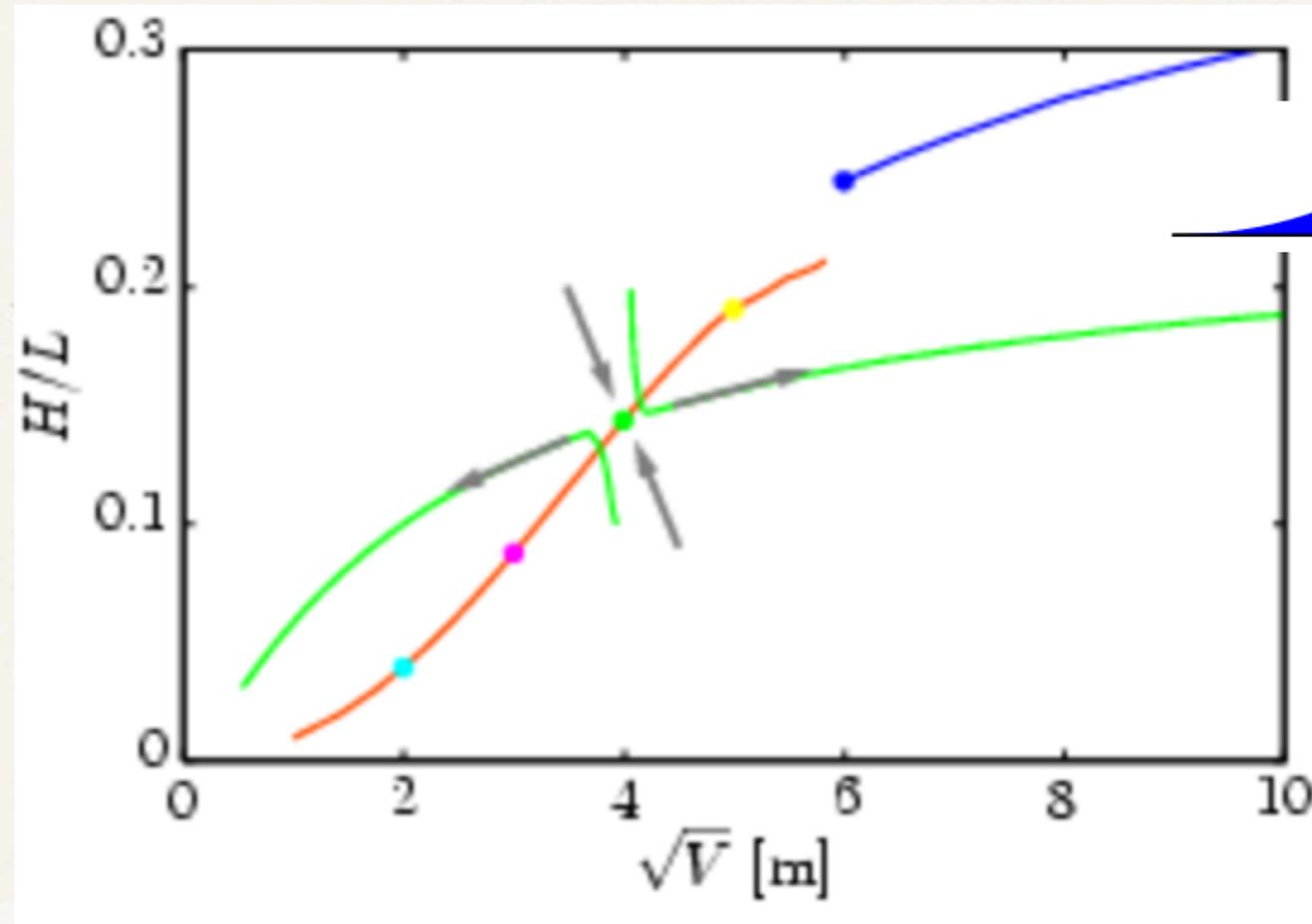
*Physik Department, TU München, 85748 Garching, Germany*

Michael E. Cates

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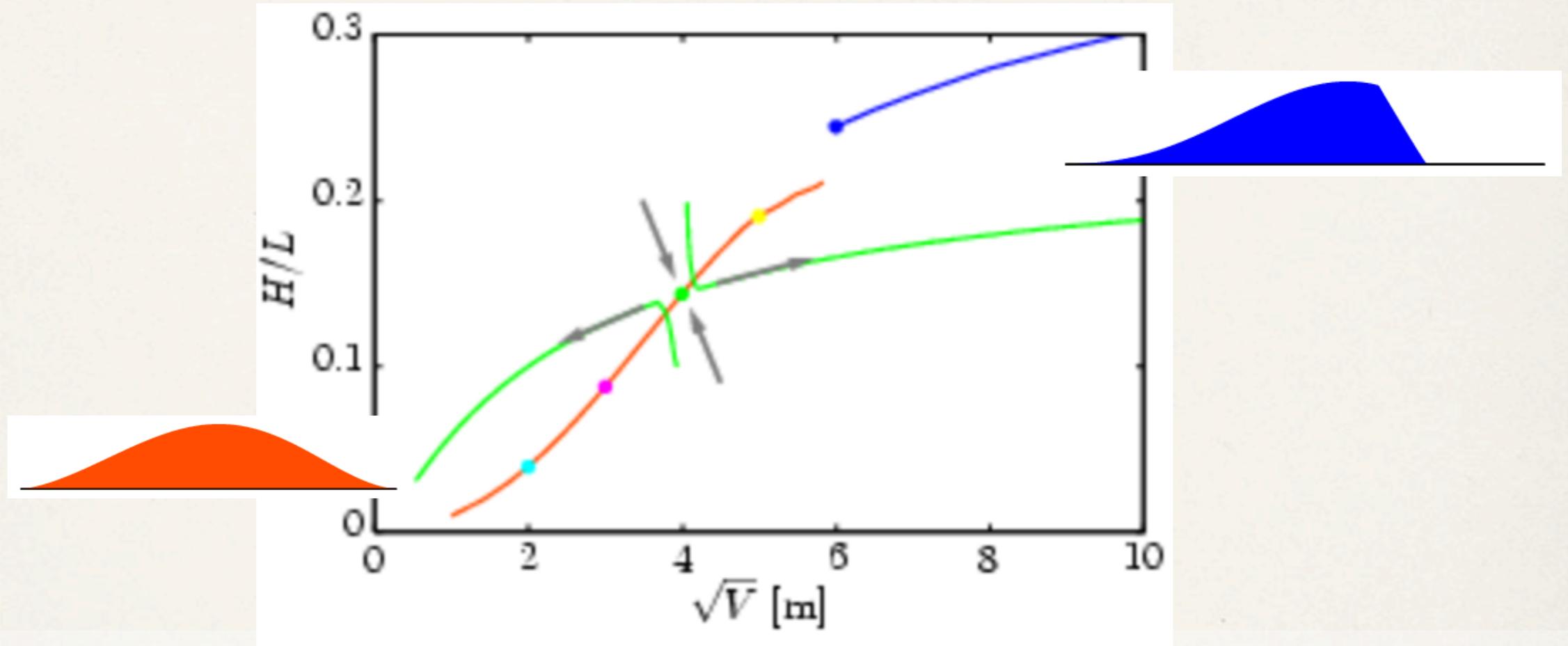
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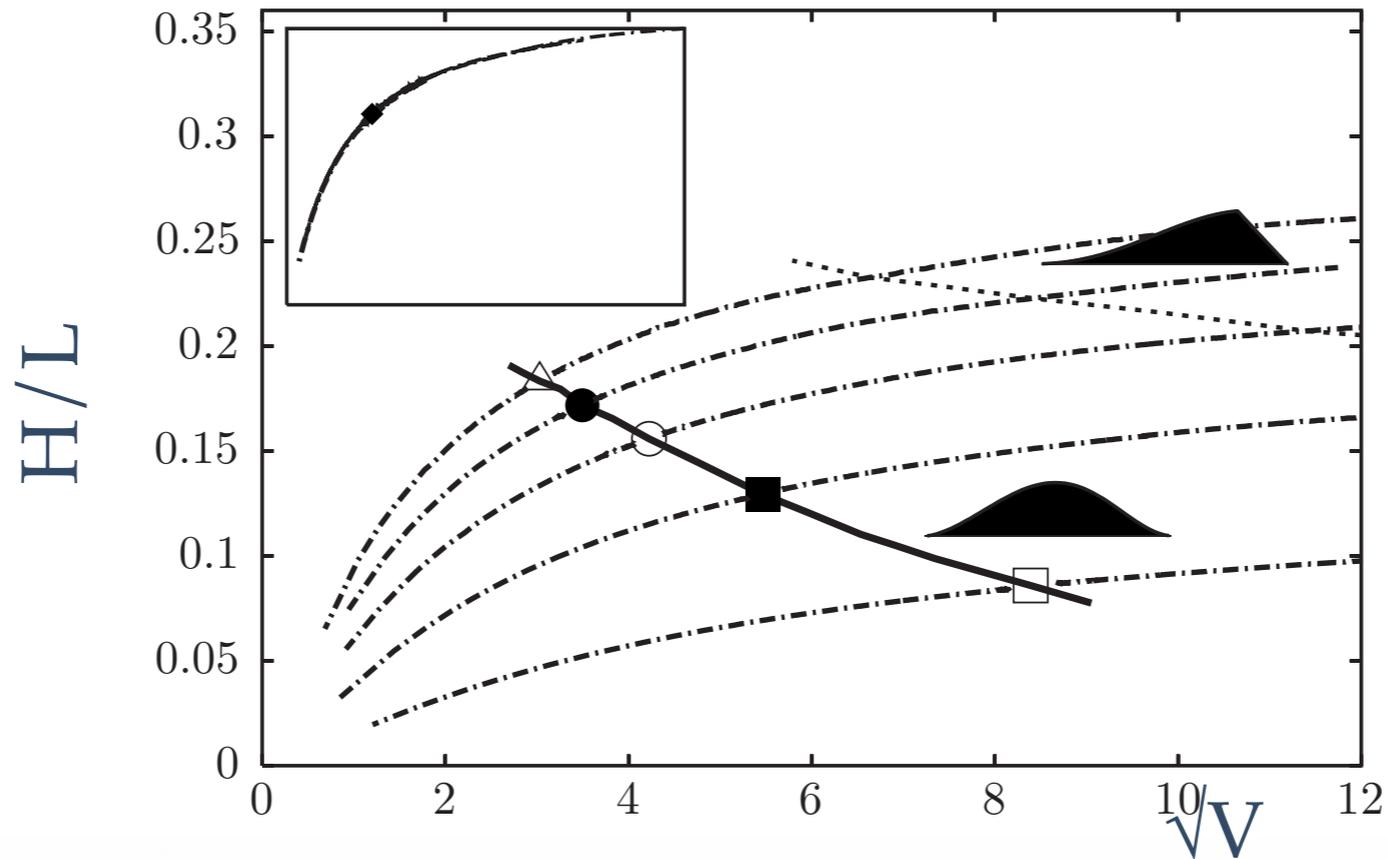
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# Hydrodynamic Models

- Conservation laws  $\rightarrow$  robustly sensible behavior
- Kinetic coefficients  $\rightarrow$  more subtle than EOM's
- Hydrodynamic boundary conditions  
 $\neq$  conditions at the boundary

# Grain-Scale Predictions?

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For example: turbulent closure with airborne grains

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Owen's hypothesis:

shear stress @ ground = impact threshold

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Owen's hypothesis:

shear stress @ ground = impact threshold

allegedly inconsistent with

- lab experiments on splash
- wind-profile simulations
- the Bagnold focus
- grain speed measurements

IOP PUBLISHING

Rep. Prog. Phys. 75 (2012) 106901 (72pp)

REPORTS ON PROGRESS IN PHYSICS

[doi:10.1088/0034-4885/75/10/106901](https://doi.org/10.1088/0034-4885/75/10/106901)

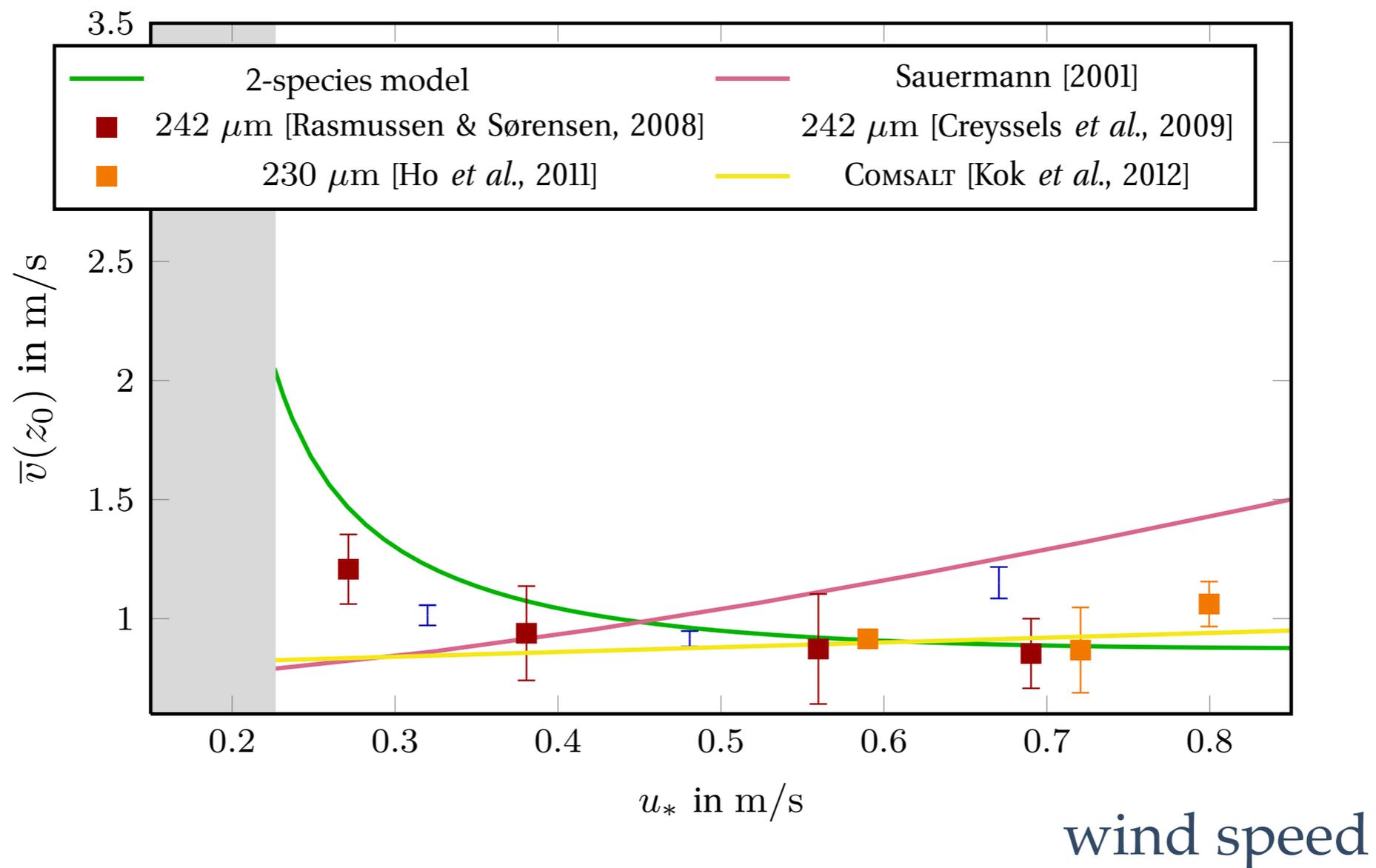
## The physics of wind-blown sand and dust

Jasper F Kok<sup>1</sup>, Eric J R Parteli<sup>2,3</sup>, Timothy I Michaels<sup>4</sup> and Diana Bou Karam<sup>5</sup>

**“We thus conclude that Owen's hypothesis is incorrect and can produce incorrect results”**

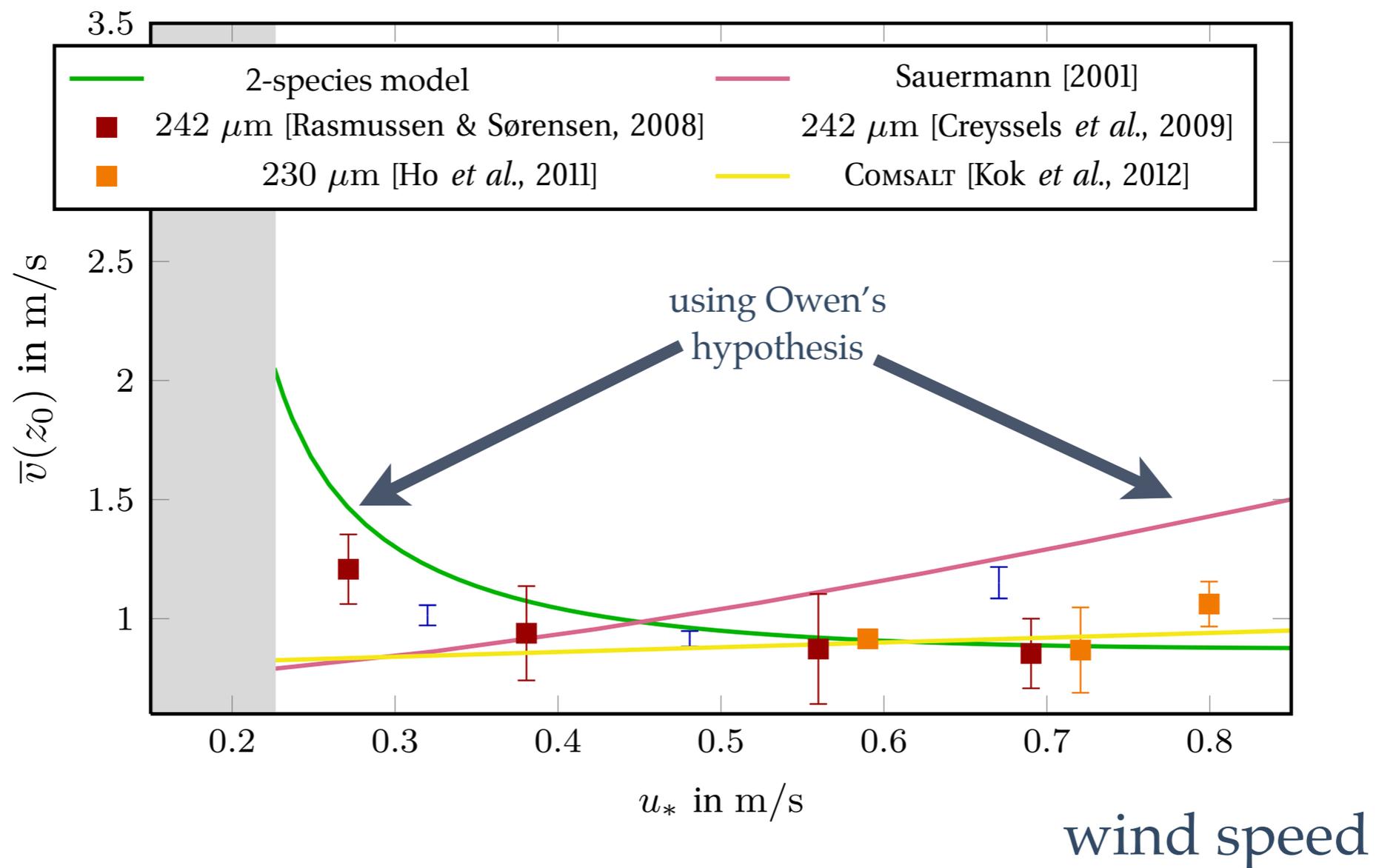
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grain speed @ ground level



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# 2-Species Model



# Turbulent Symmetry Breaking

$$\Delta\tau(x) \approx A \left[ \underbrace{\int d\xi \frac{h'(\xi)/\pi}{x-\xi}}_{\text{Bernoulli}} + \underbrace{Bh'(x)}_{\text{Reynolds}} \right]$$

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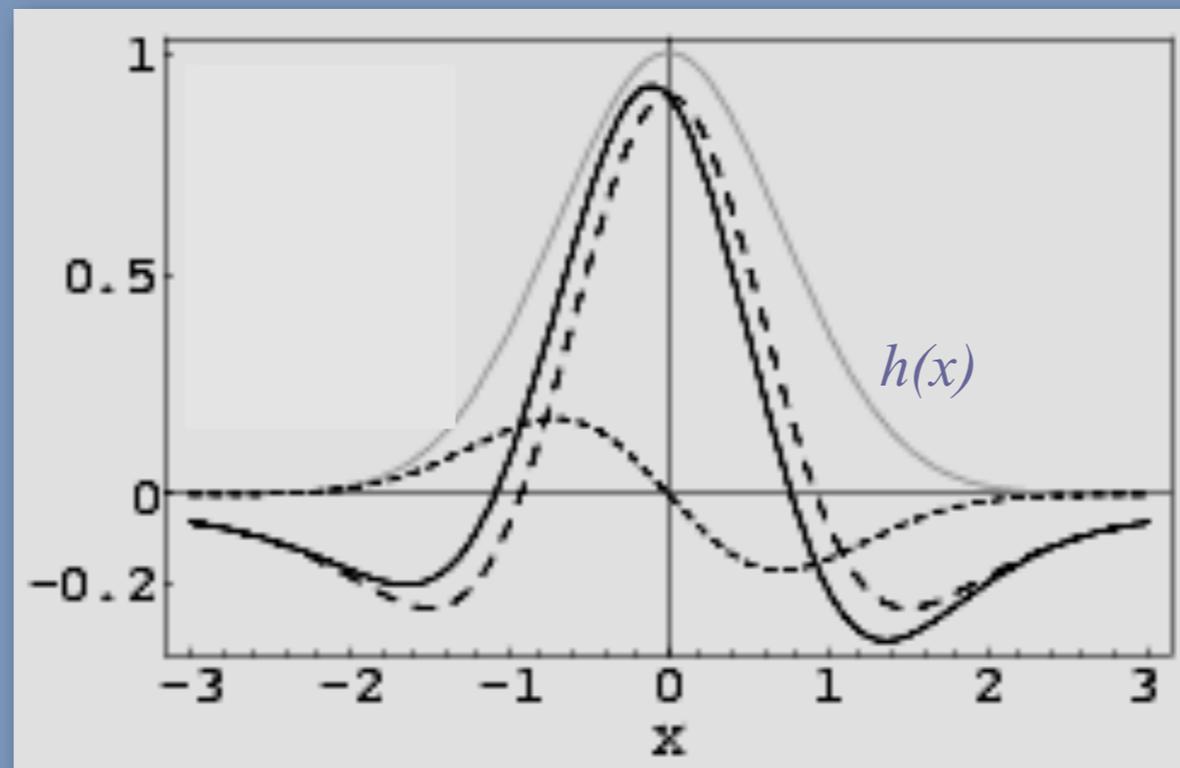
wind friction

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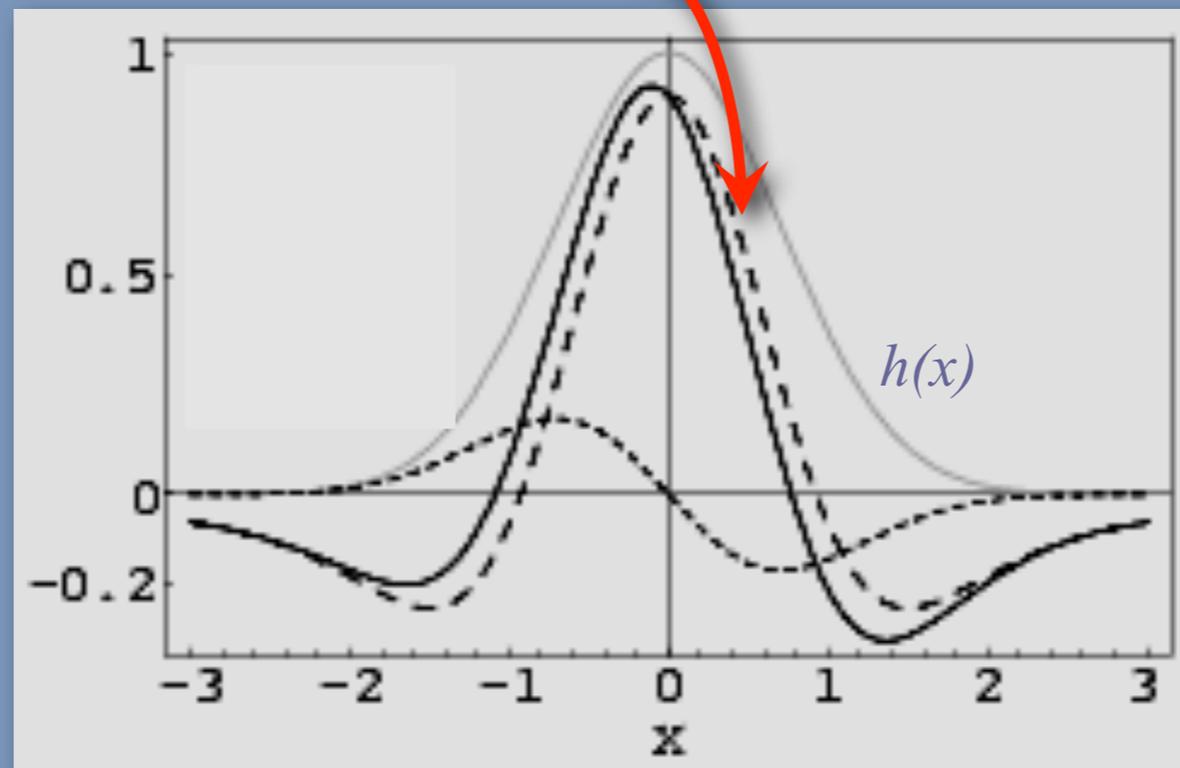
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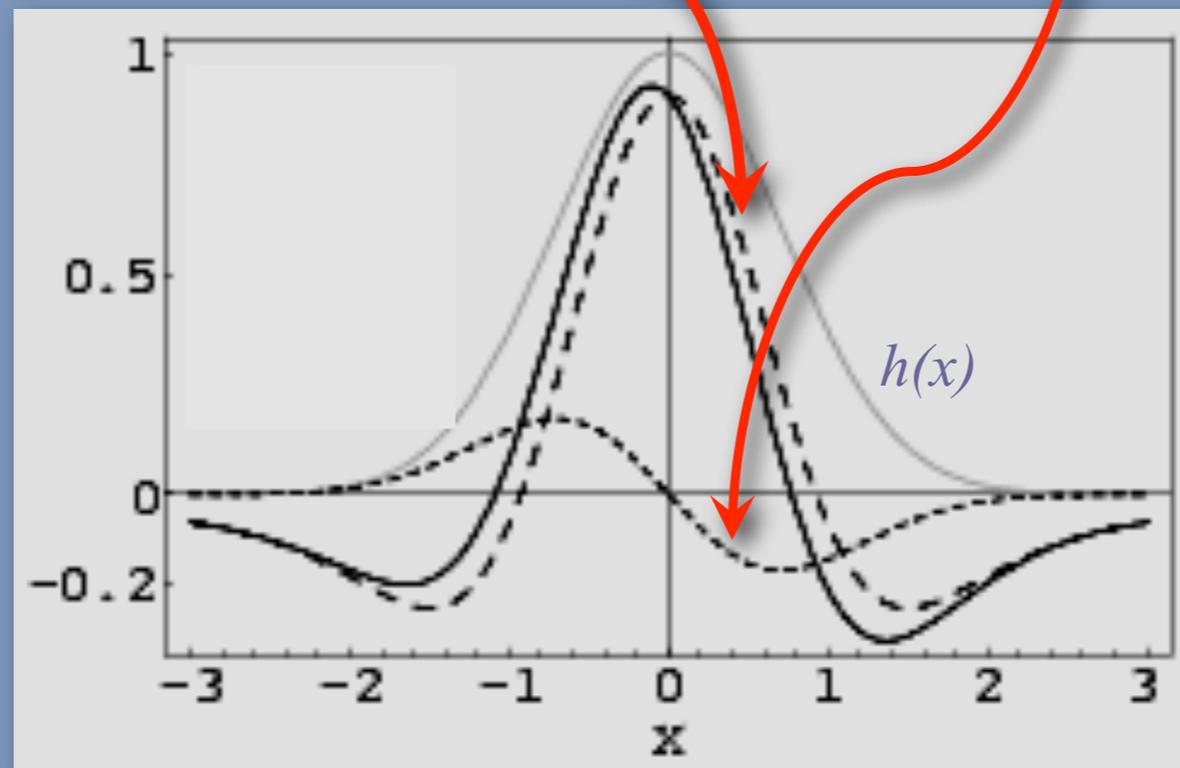
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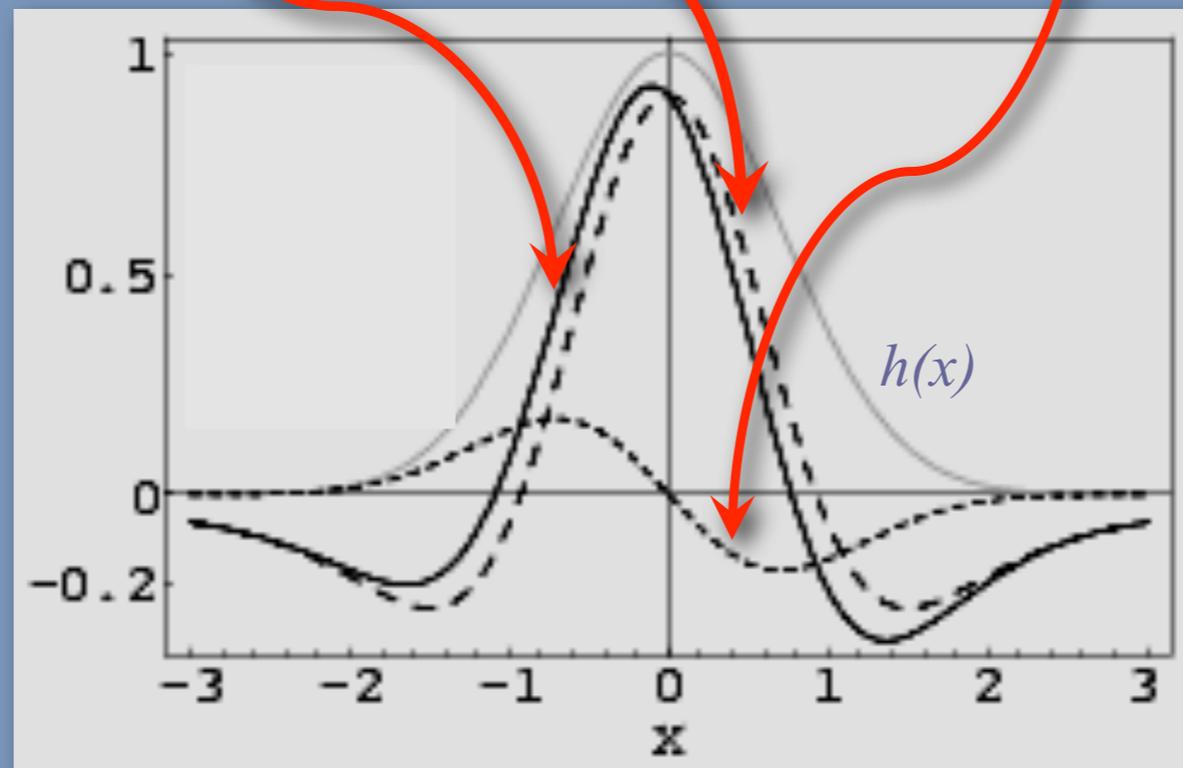
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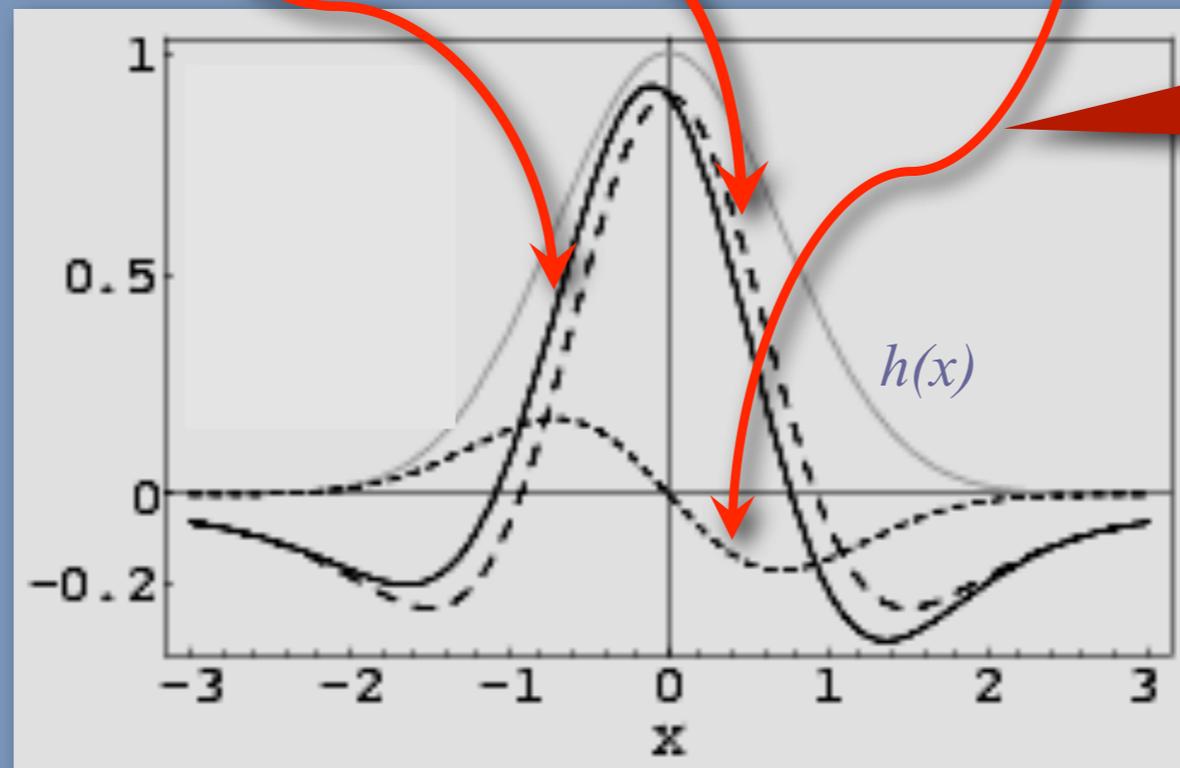
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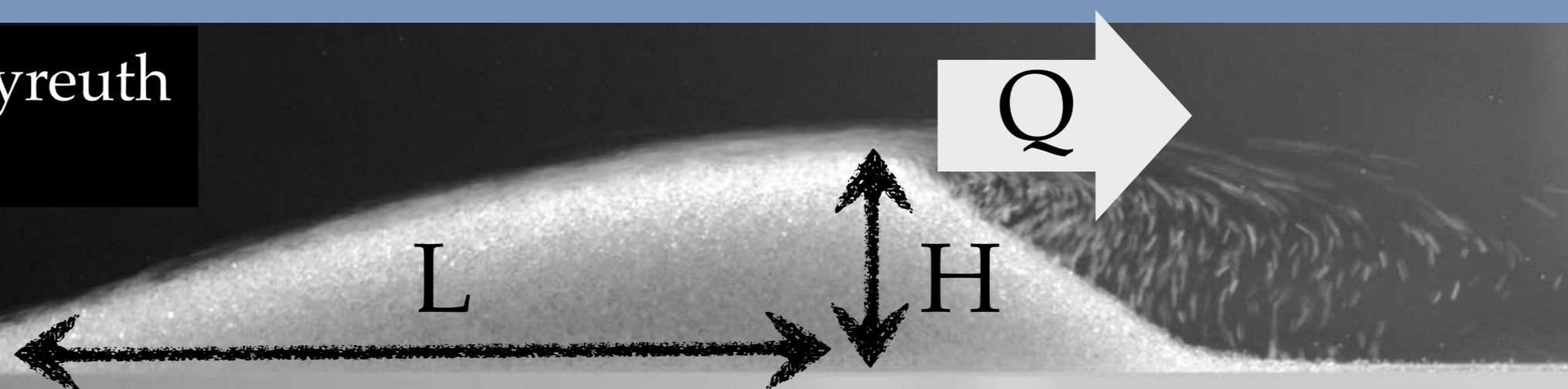
why the desert is not flat

# Scale Invariance of the Wind



Groh & Krülle, Bayreuth

3cm



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Groh & Krülle, Bayreuth

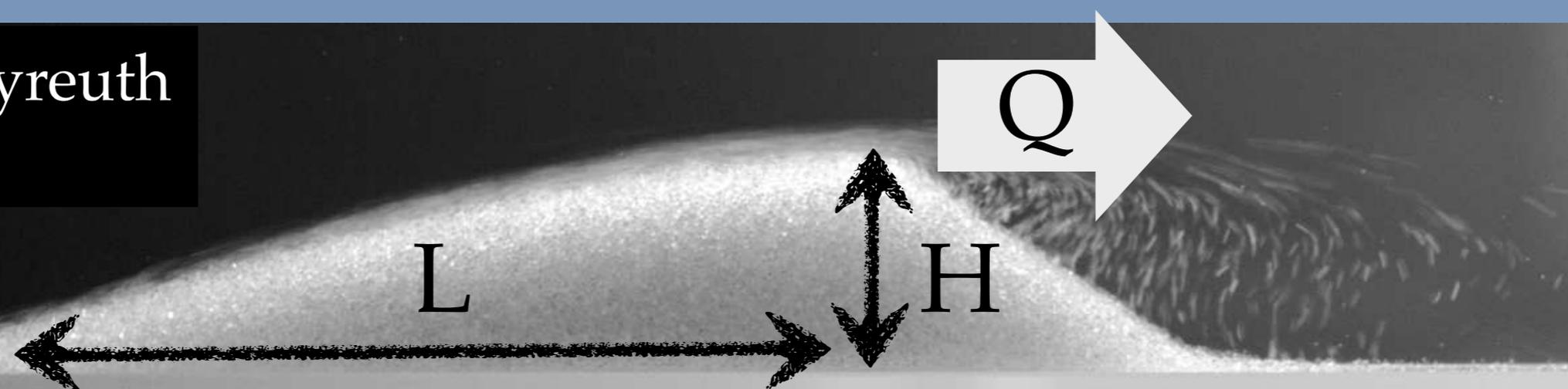


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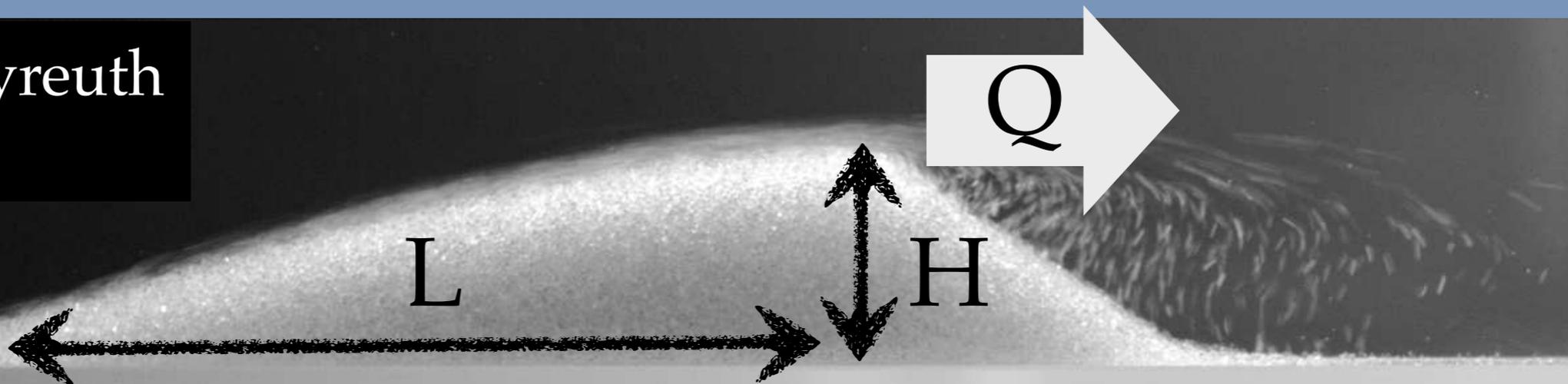
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 $V \propto Q/H$   
epigones:  
 $V \propto 1/H?$

but

$$Q \propto U(H)$$

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scale-invariant  
turbulence

$$U(H) \propto H/L$$

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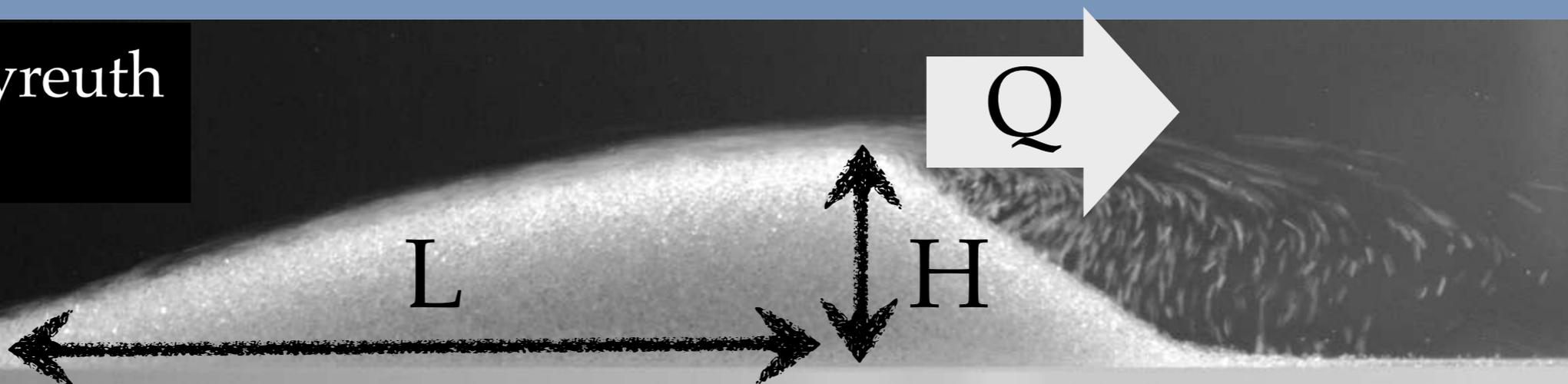
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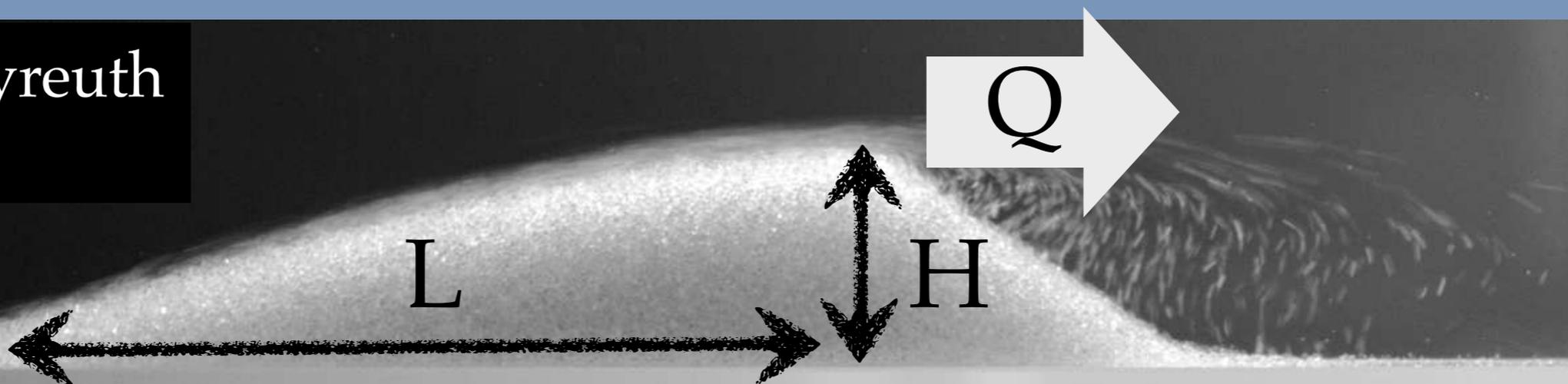
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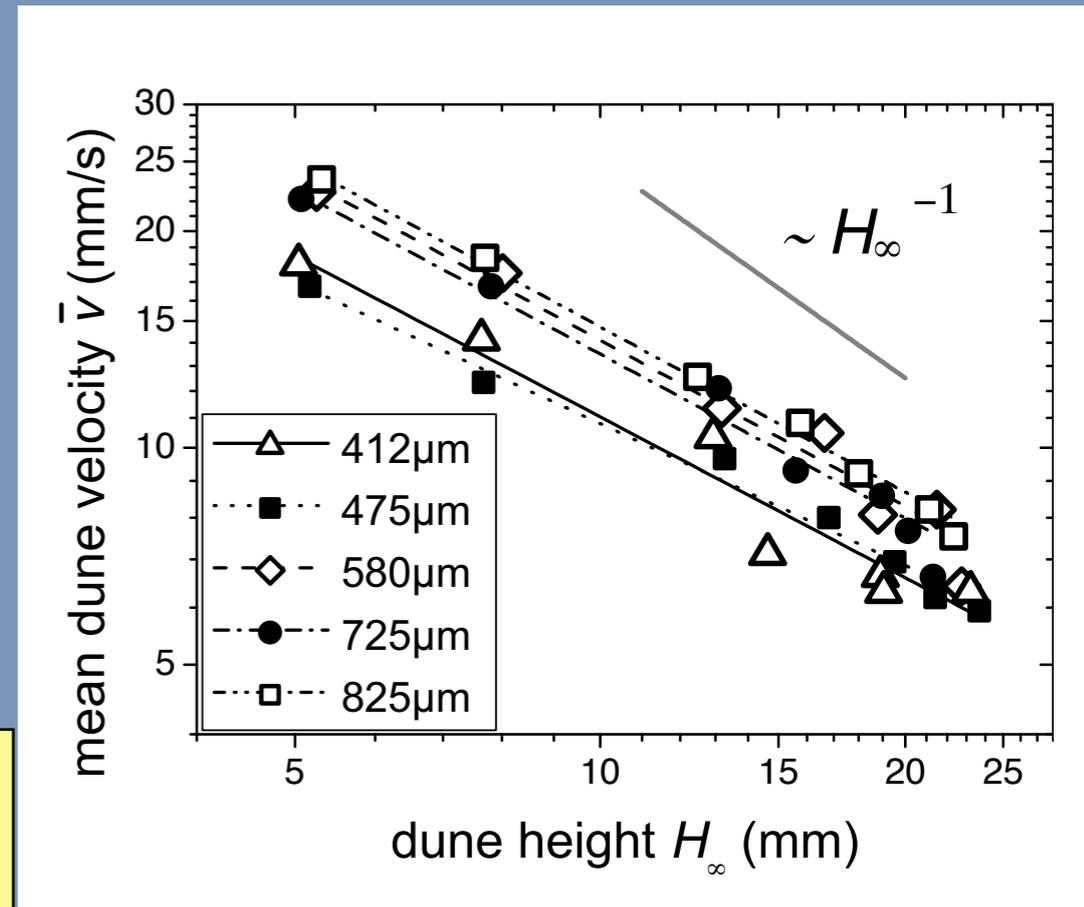
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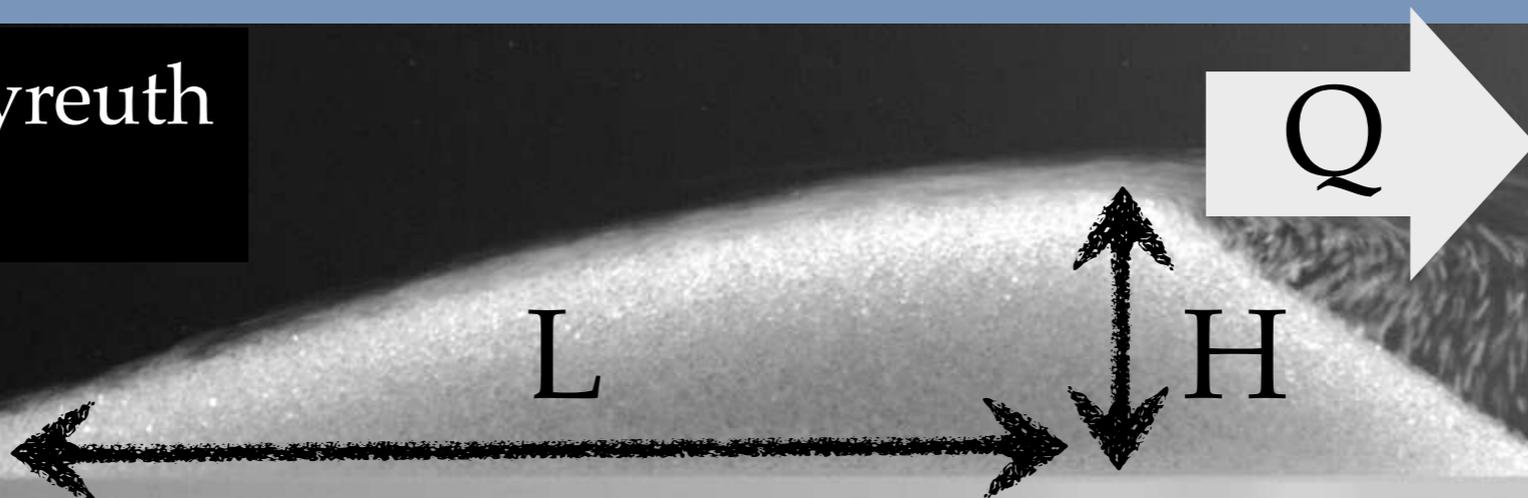
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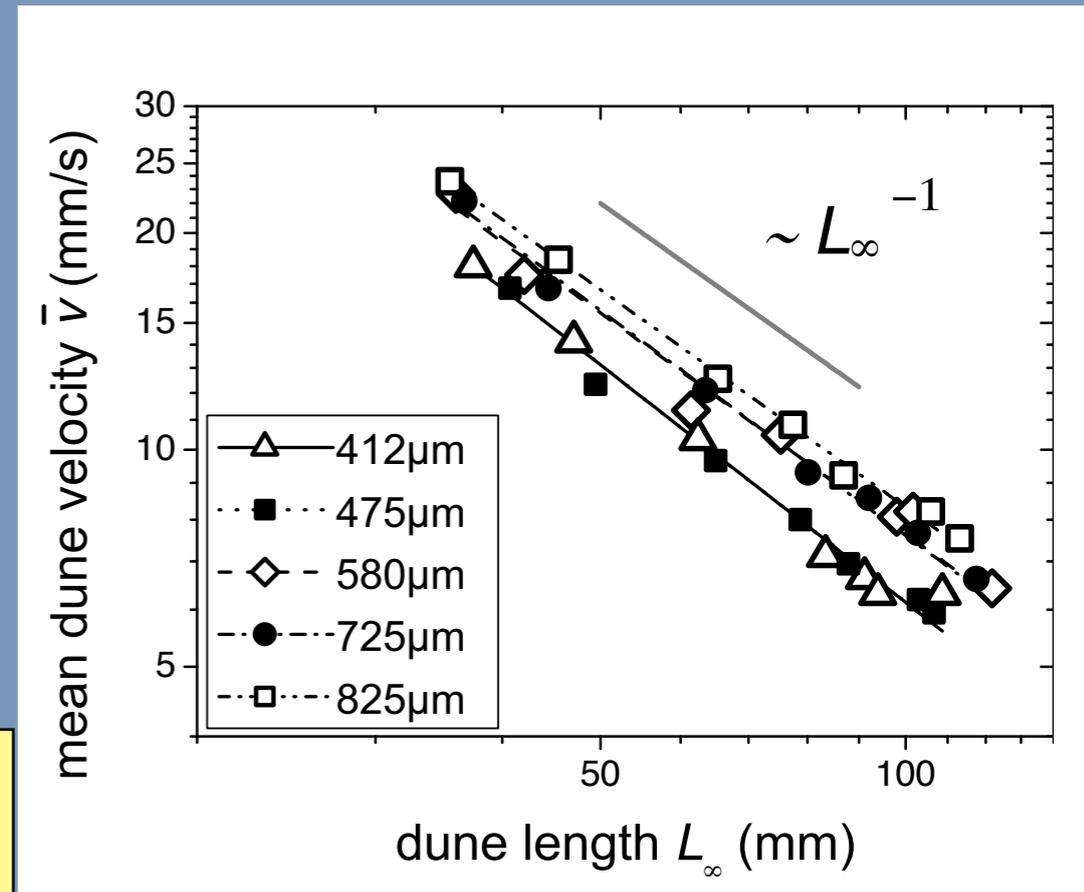
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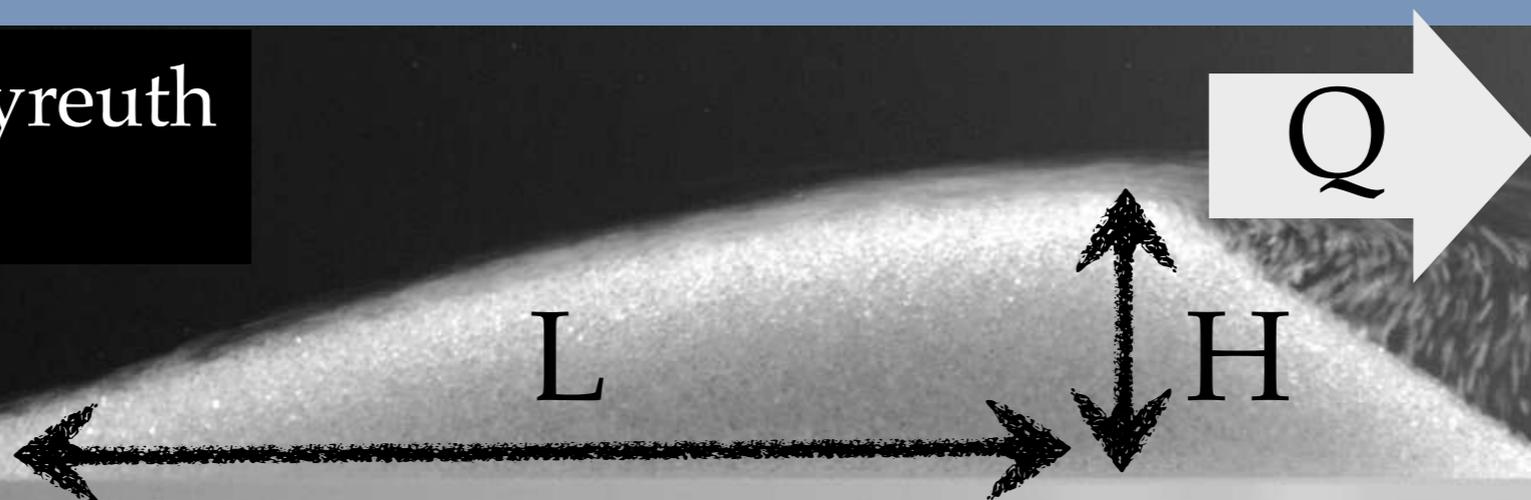
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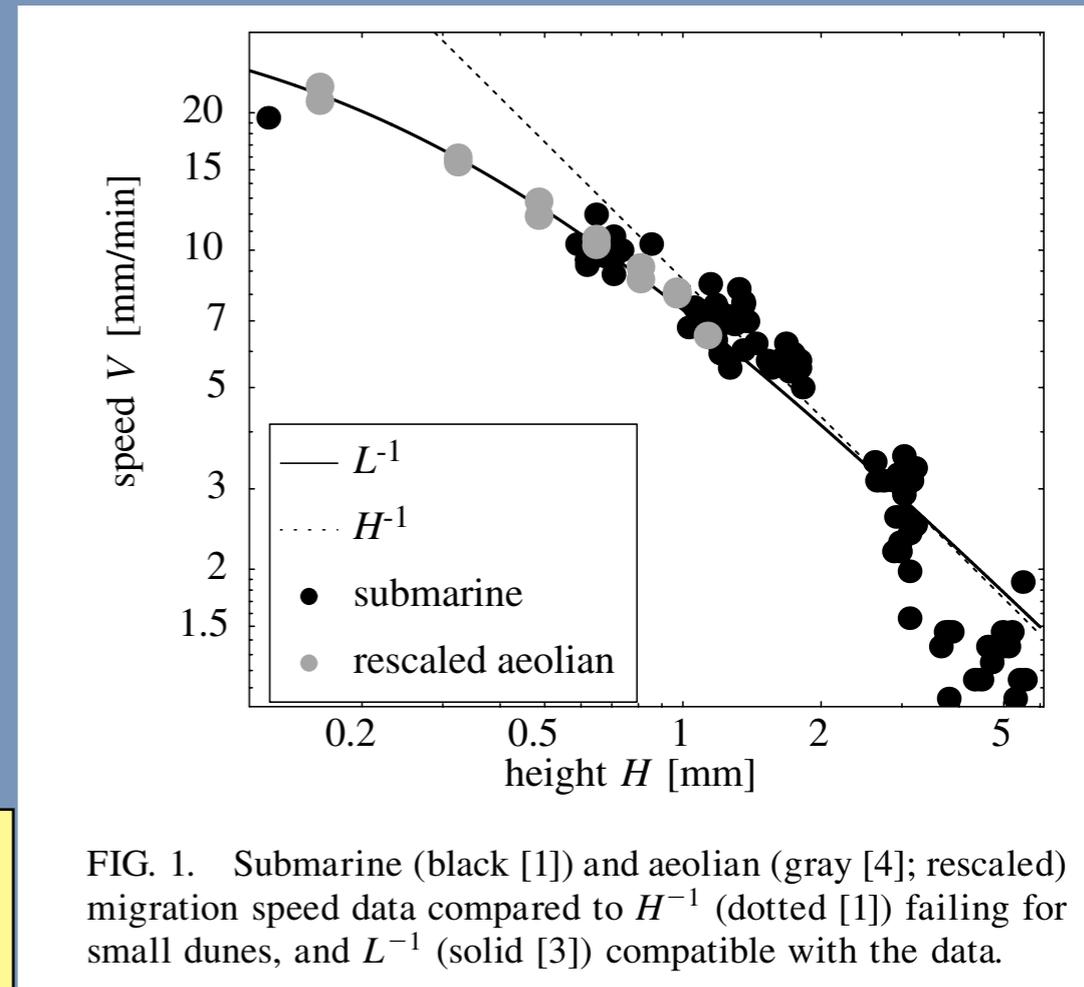
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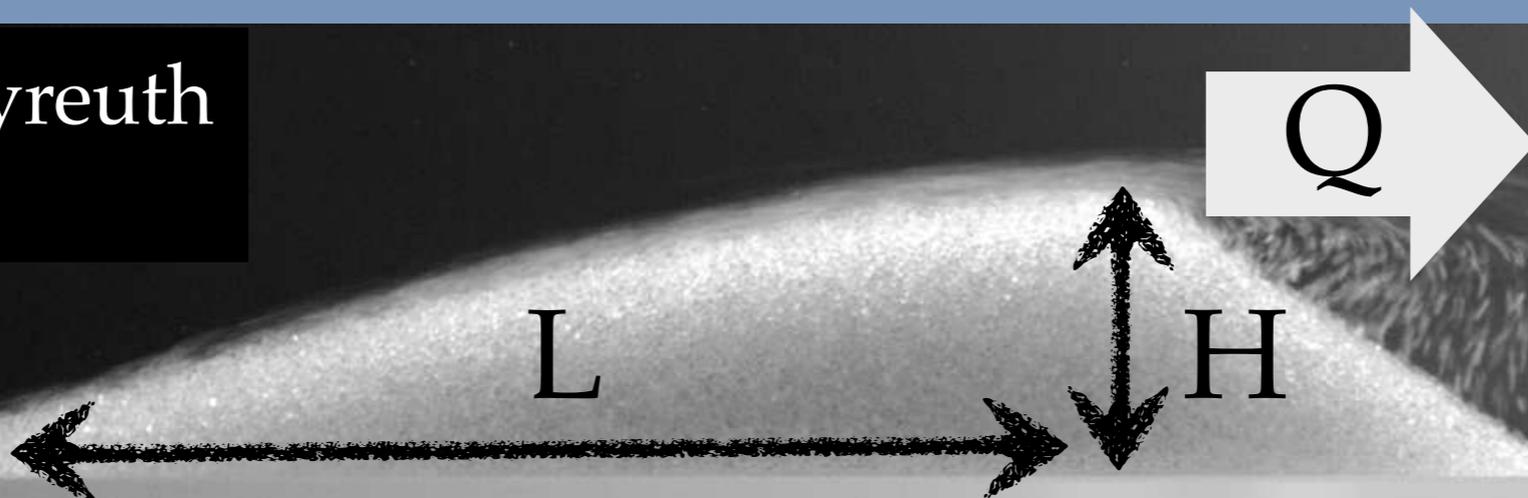
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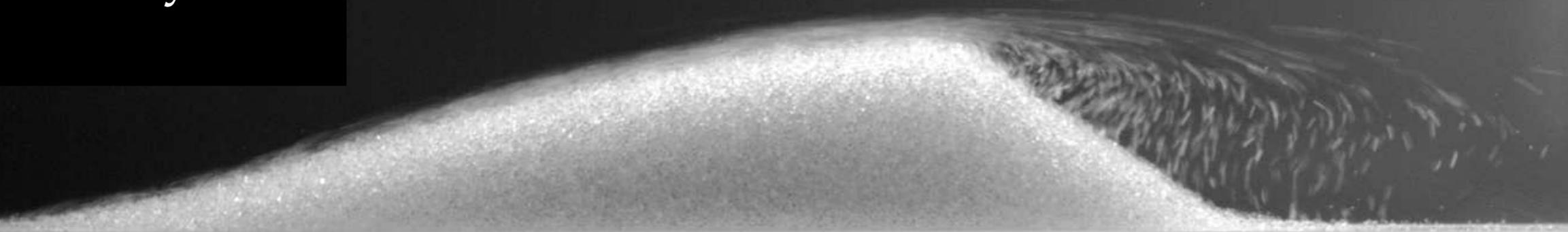
# Broken Scale Invariance of Dunes

$$L \neq H$$

since grain size breaks  
scale invariance

Groh & Krülle, Bayreuth

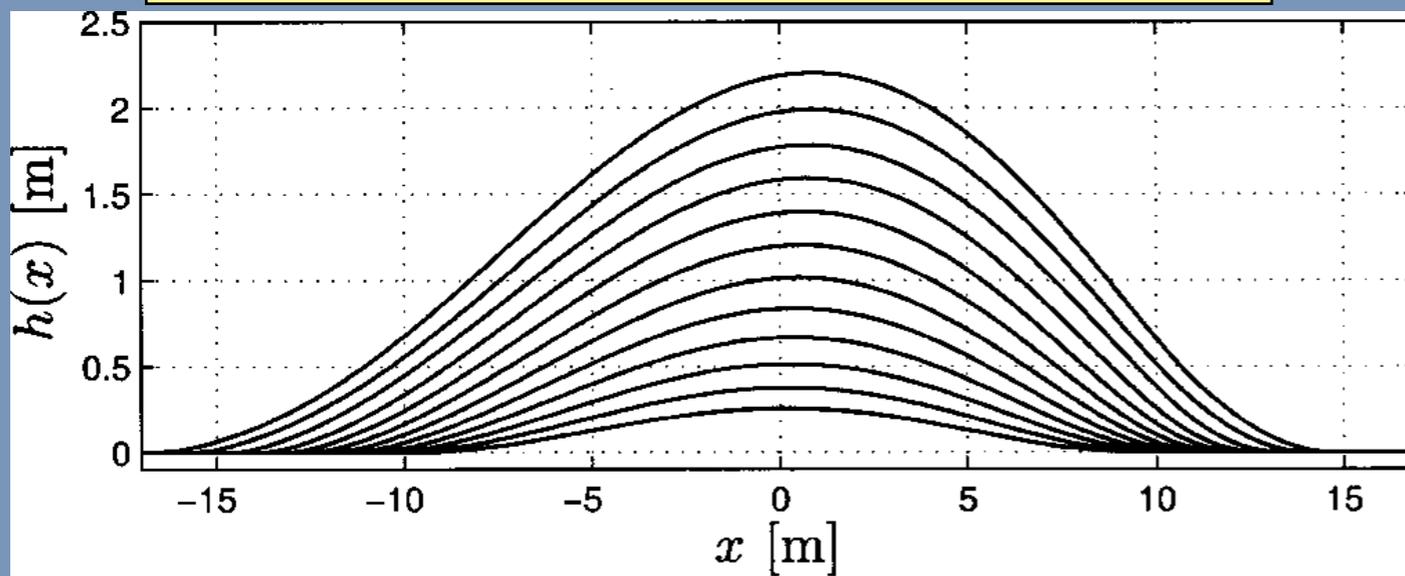
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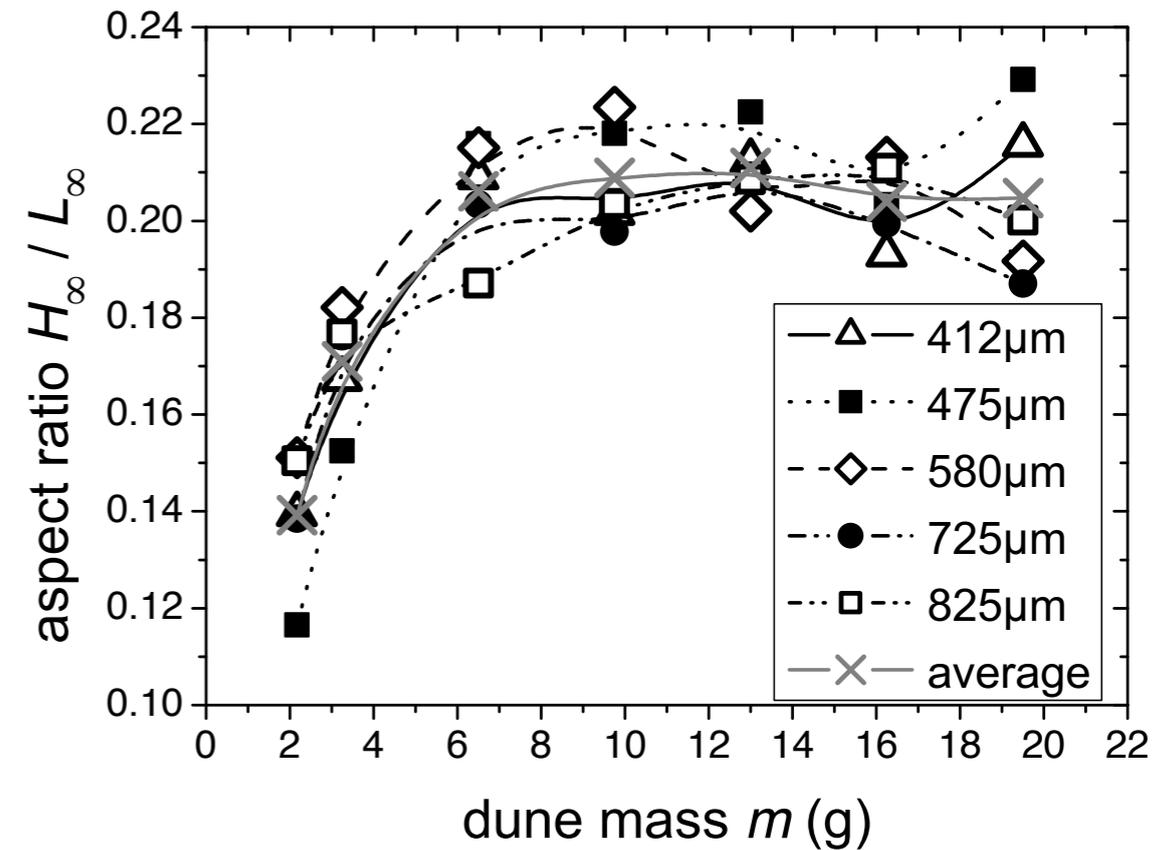
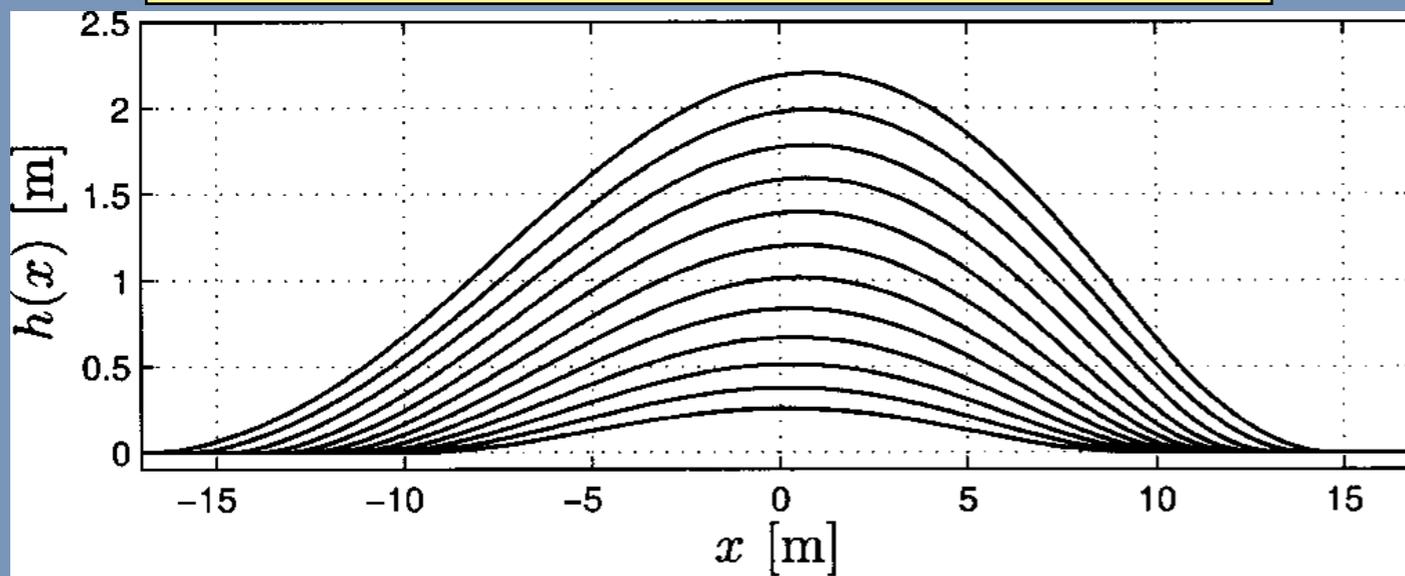


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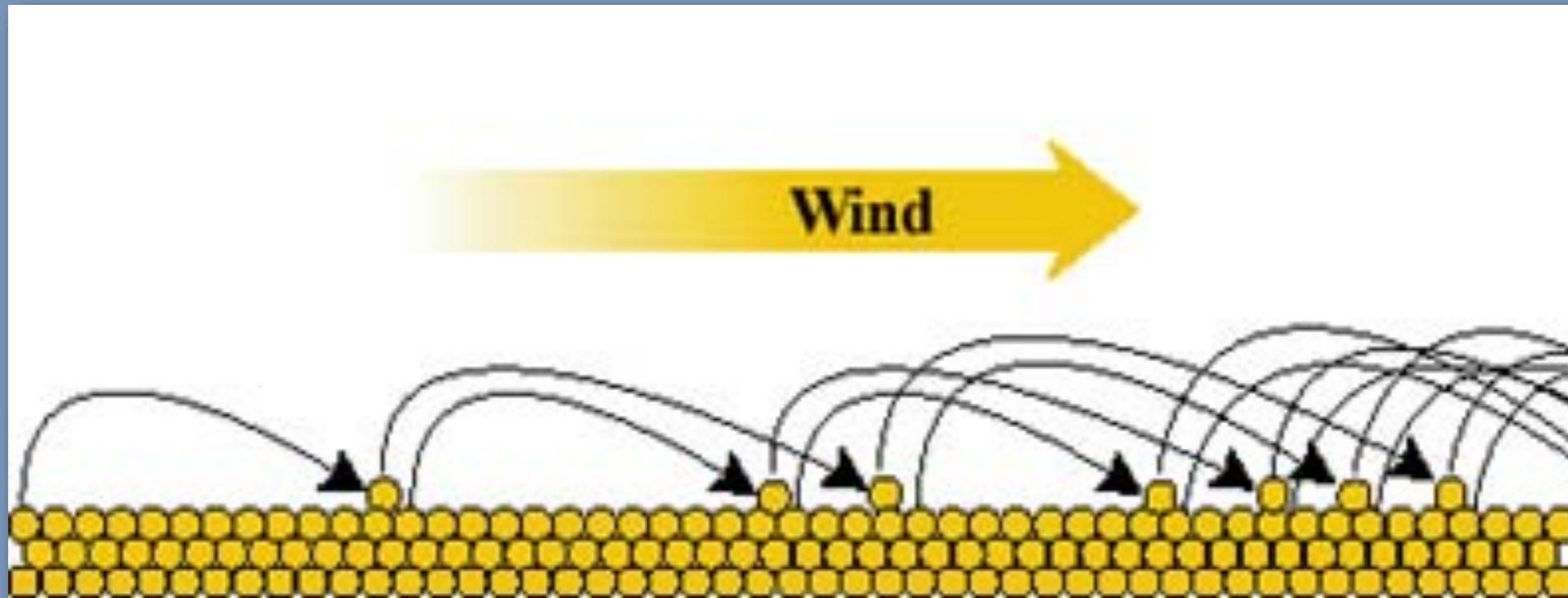


Groh & Krülle, Bayreuth

3cm

# Culprit: Saturation Gradients

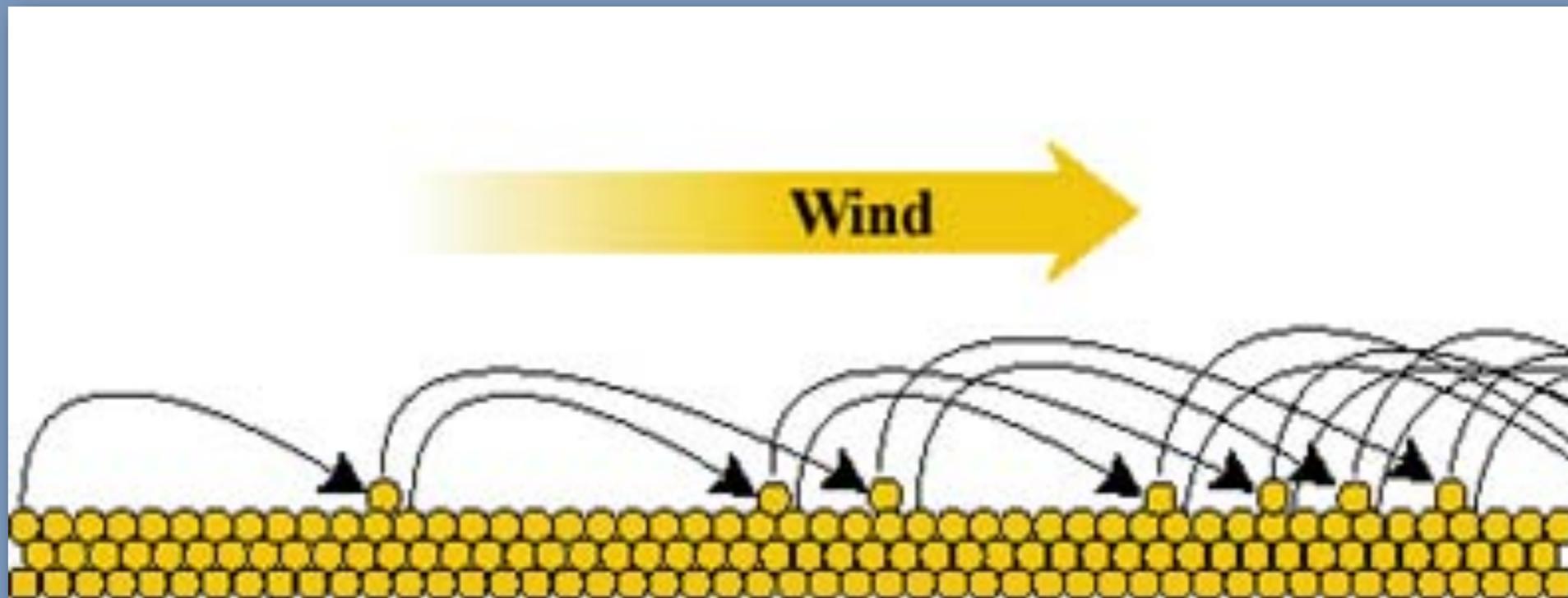
$$\ell_s(\tau)q' = q[1 - q/q_s(\tau)]$$



# Culprit: Saturation Gradients

sand flux

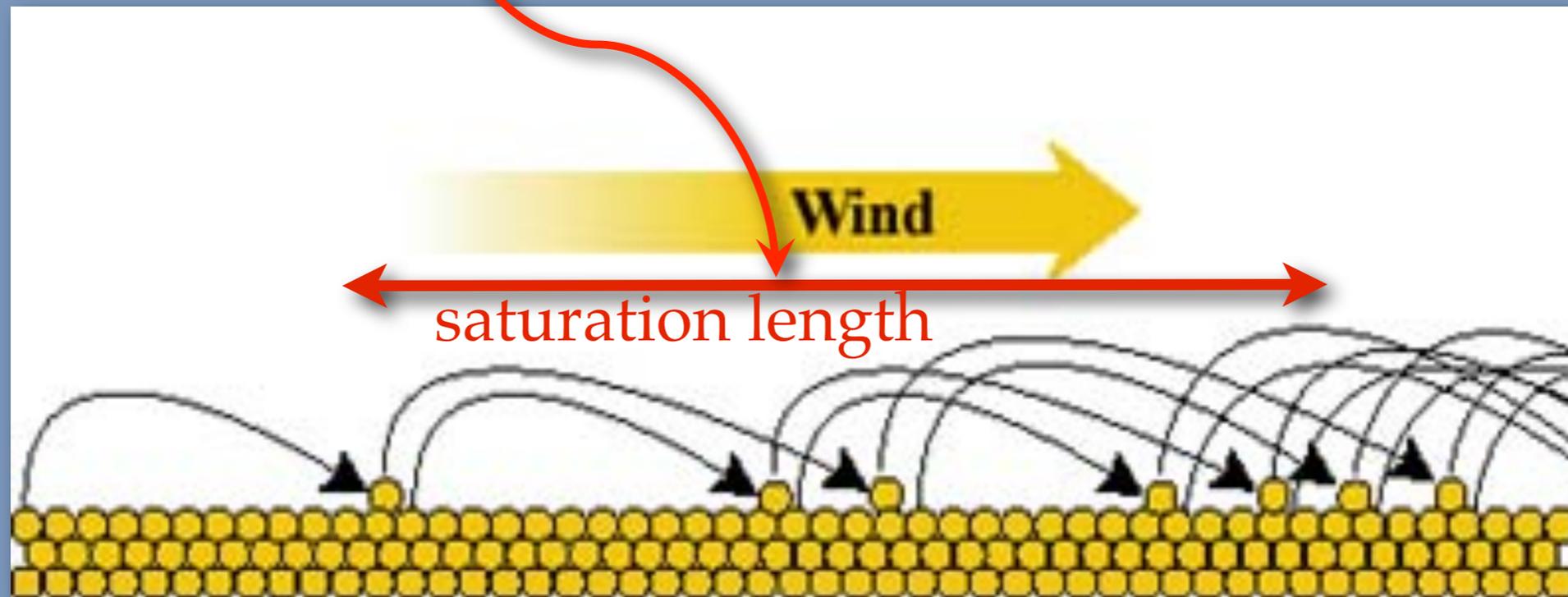
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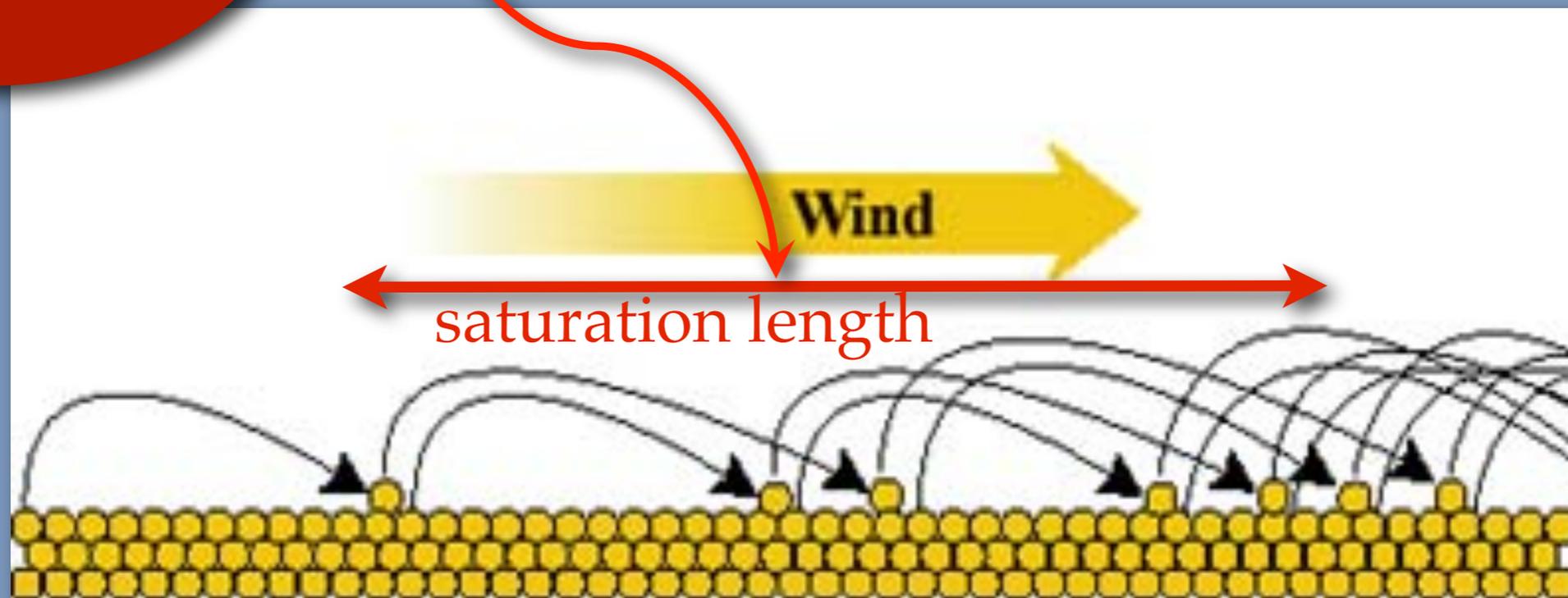


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Why dune shape is size-dependent

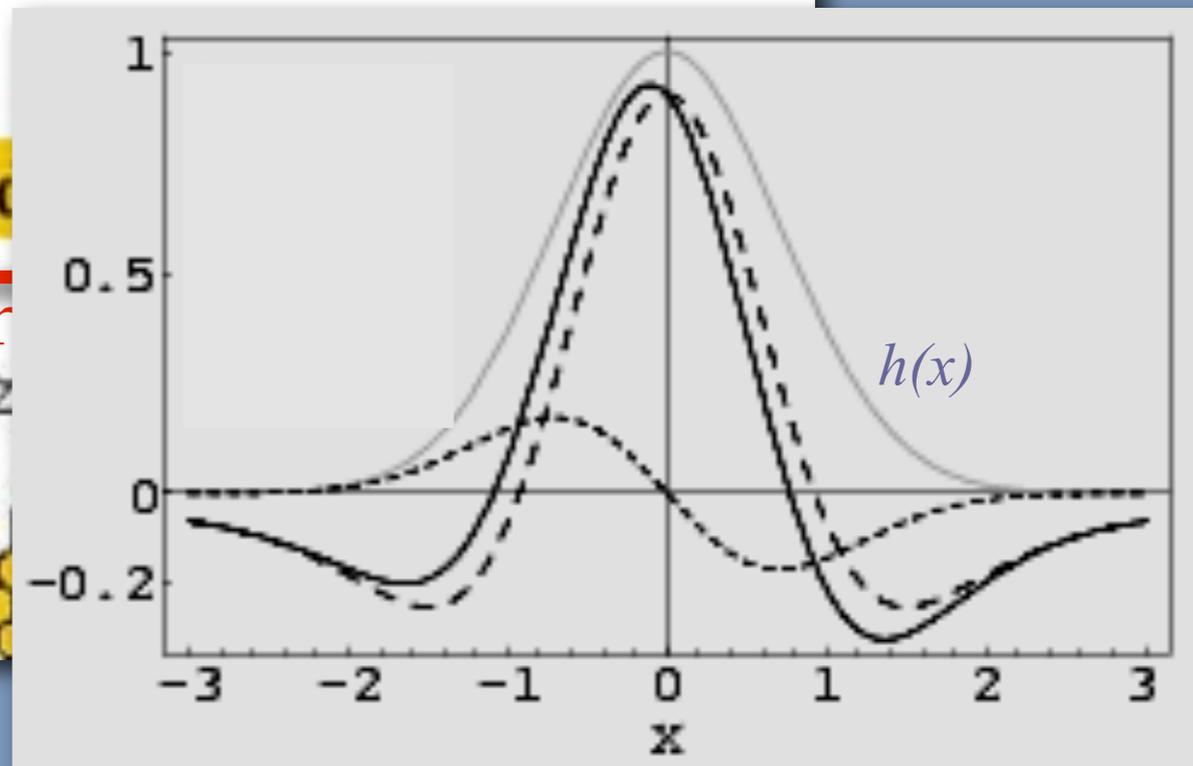
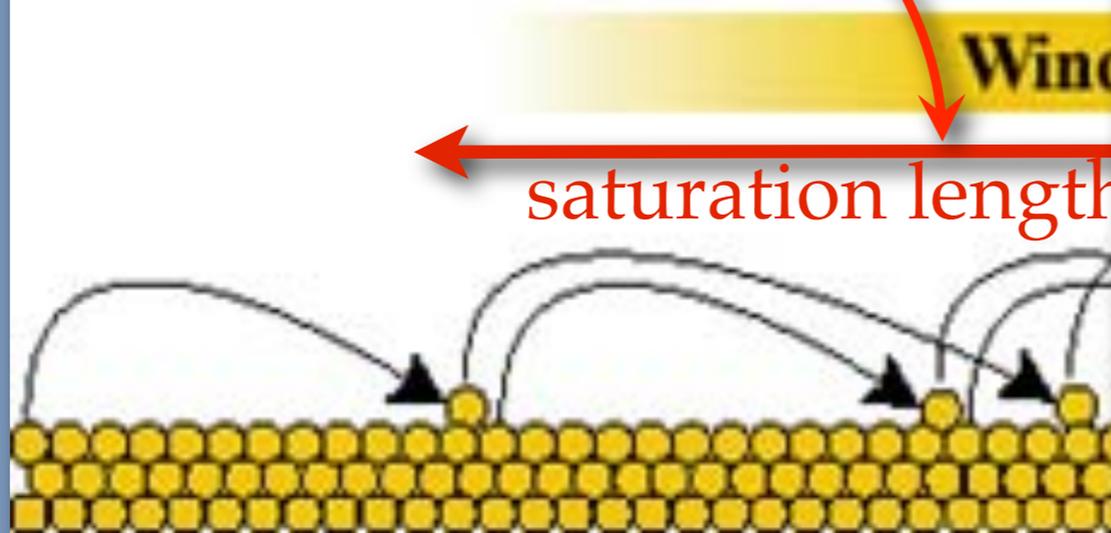


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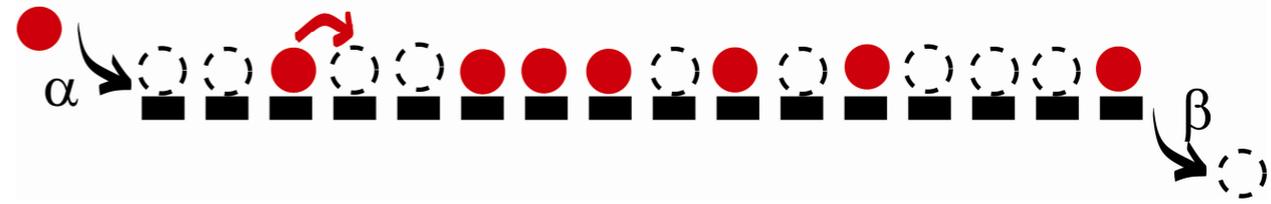
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# Magnified Noise

● particle    ○ vacancy



## Traffic Jam without Bottleneck

Experimental evidence  
for the physical mechanism of forming a jam

Yuki Sugiyama, Minoru Fukui, Macoto Kikuchi,  
Katsuya Hasebe, Akihiro Nakayama, Katsuhiro Nishinari,  
Shin-ichi Tadaki and Satoshi Yukawa

Movie 1

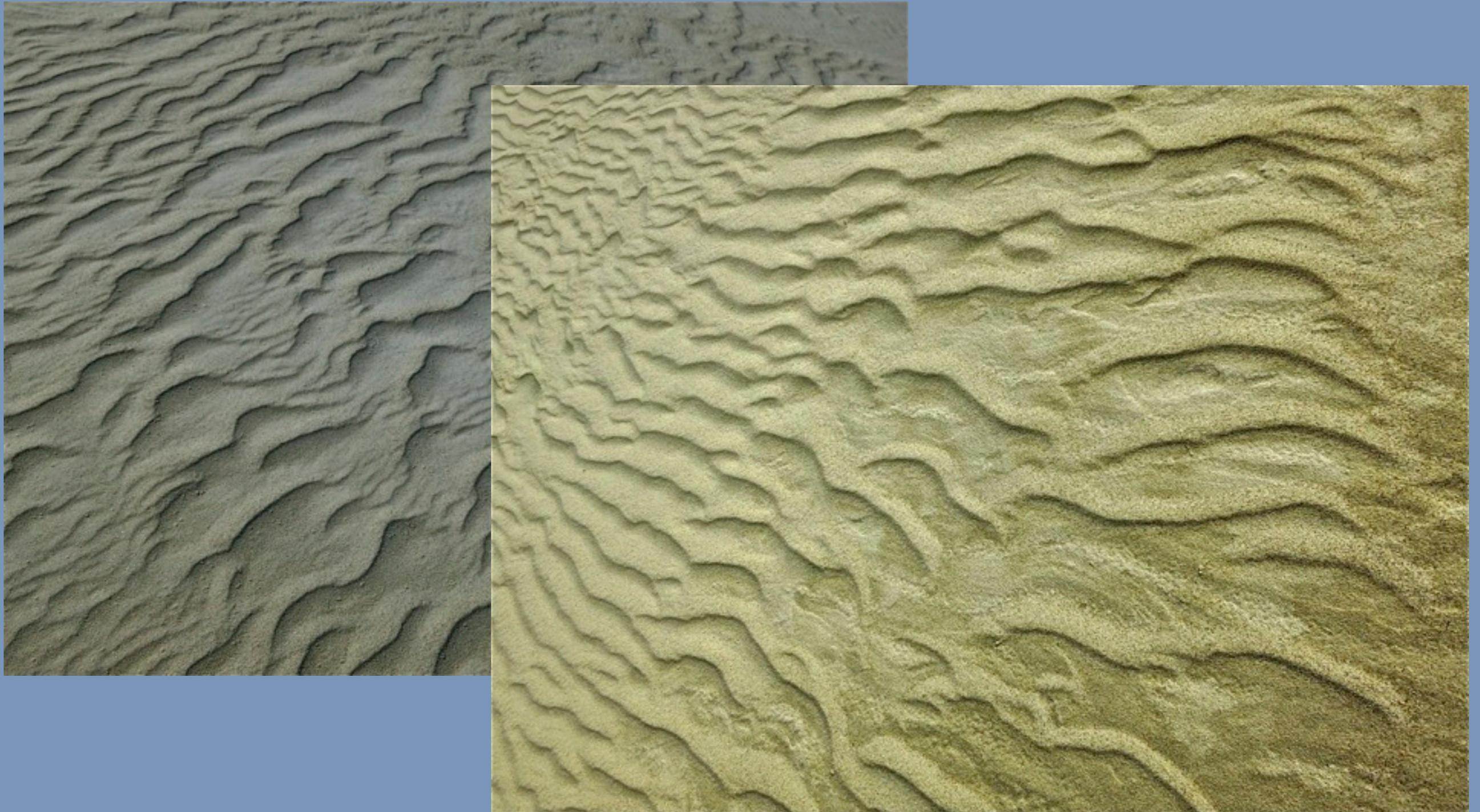


The Mathematical Society of Traffic Flow

# Some Plans for Our Stay @ KITP



# Some Plans for Our Stay @ KITP



# Thank you for your attention

