Title: Emergent Pattern Formation

Date: Oct 14, 2011 05:30 PM

URL: http://pirsa.org/11100107

Abstract:

Emergent pattern formation

- dribbling syrup
- washboard road
- rotating icicles

Stephen Morris, University of Toronto Physics


Jackson Pollock *Untitled 1948/49*


Jackson Pollock *Untitled 1948/49*
detail

The Fluid Mechanical Sewing Machine

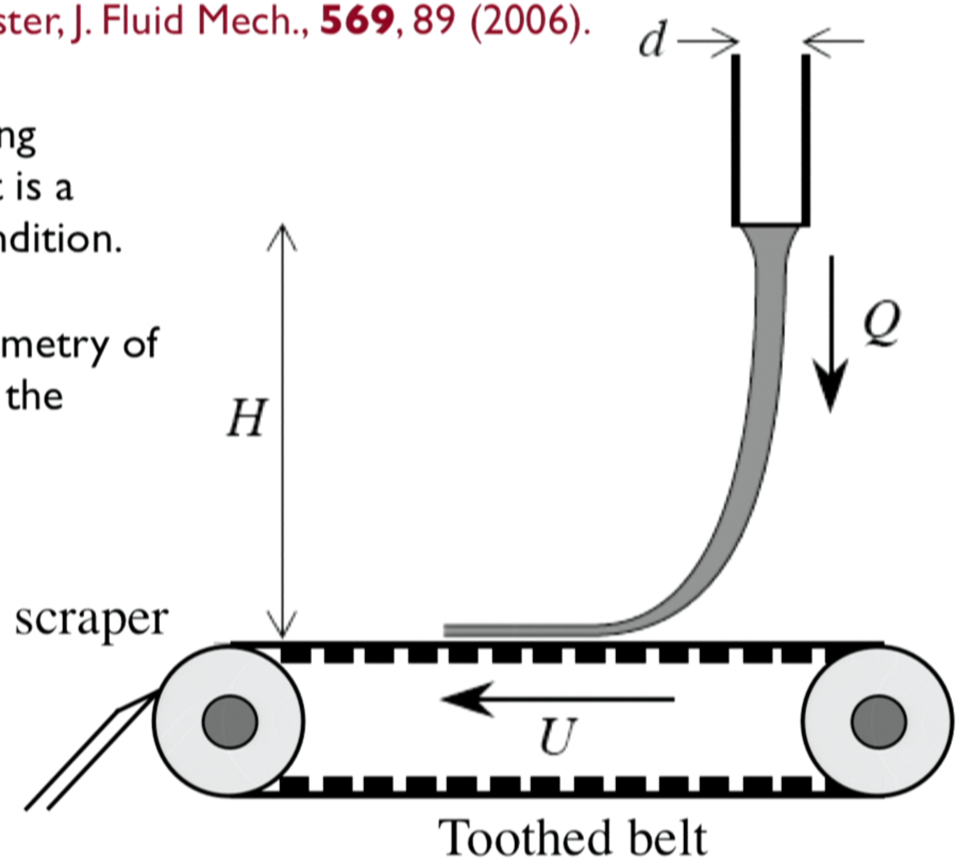
S. Chiu-Webster and J. R. Lister, J. Fluid Mech., **569**, 89 (2006).

Improves on the classic coiling experiment because the belt is a better defined boundary condition.

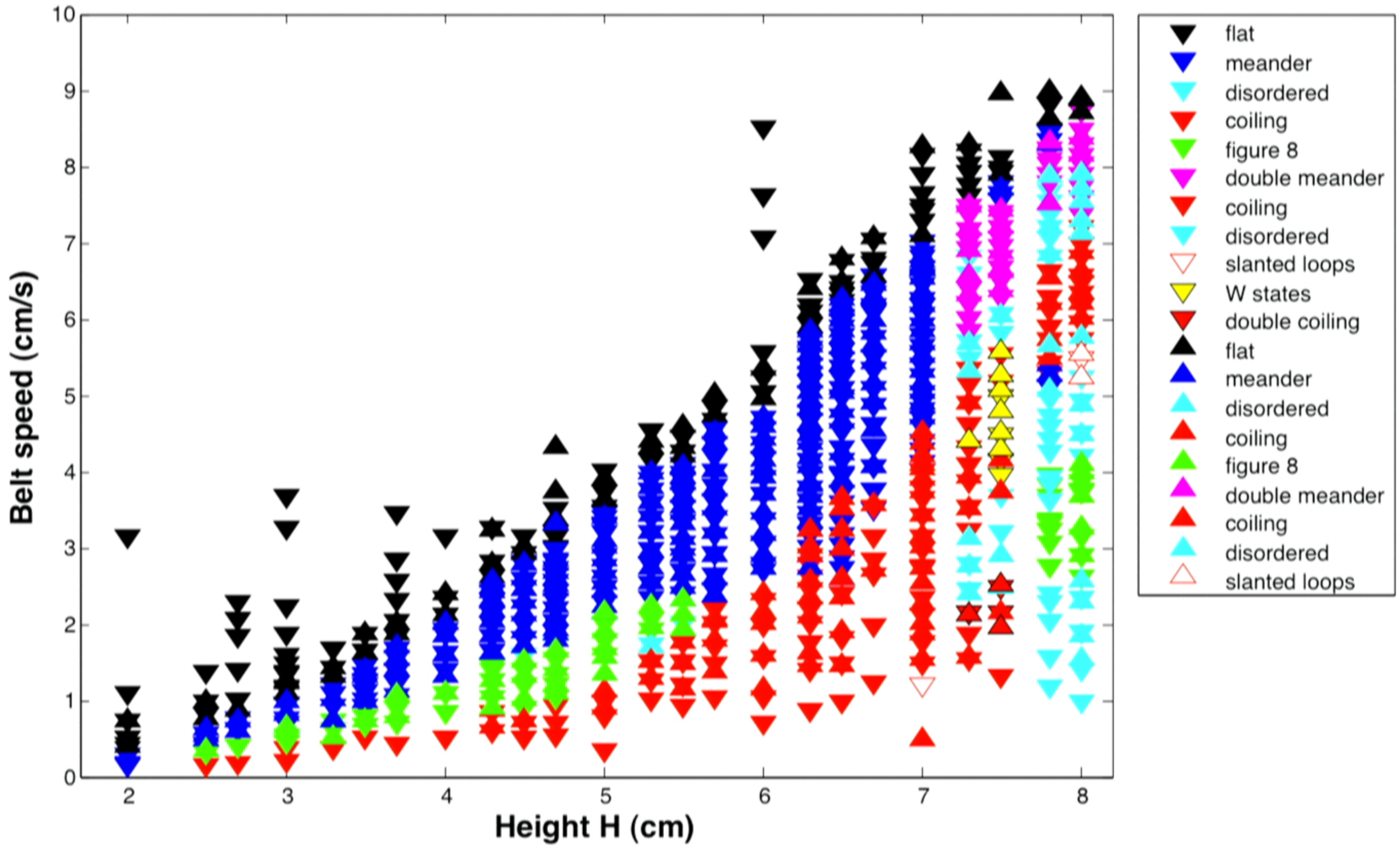
Translation breaks O(2) symmetry of the basic coiling and unfolds the coiling bifurcation.

Control parameters:

H and U



A zoo of states and bifurcations



S. W. Morris, J. H. P. Dawes, N. M. Ribe, and J. R. Lister, ***Phys. Rev. E***, 77, 066218 (2008).

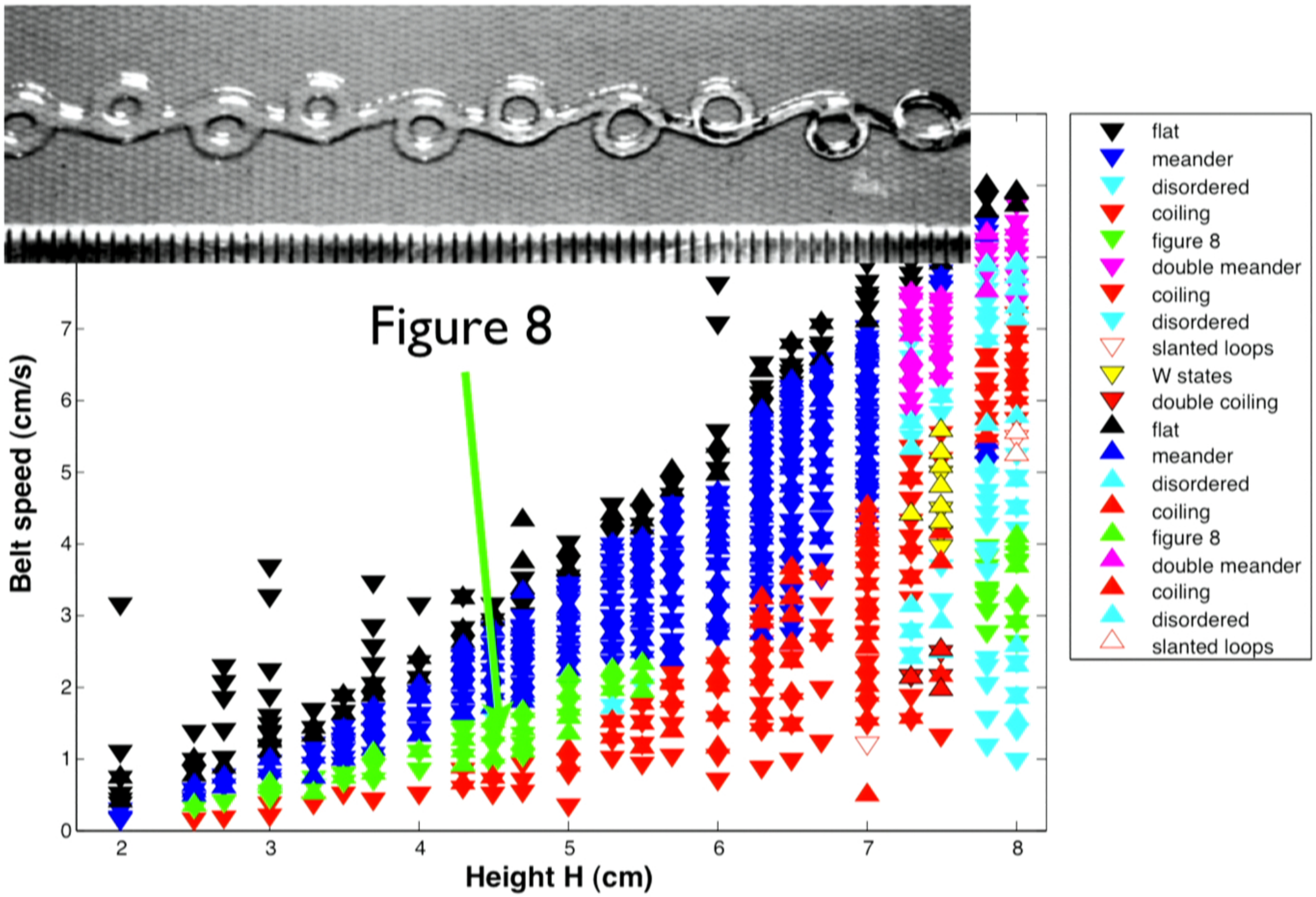


Image and movie by S. Chiu-Webster

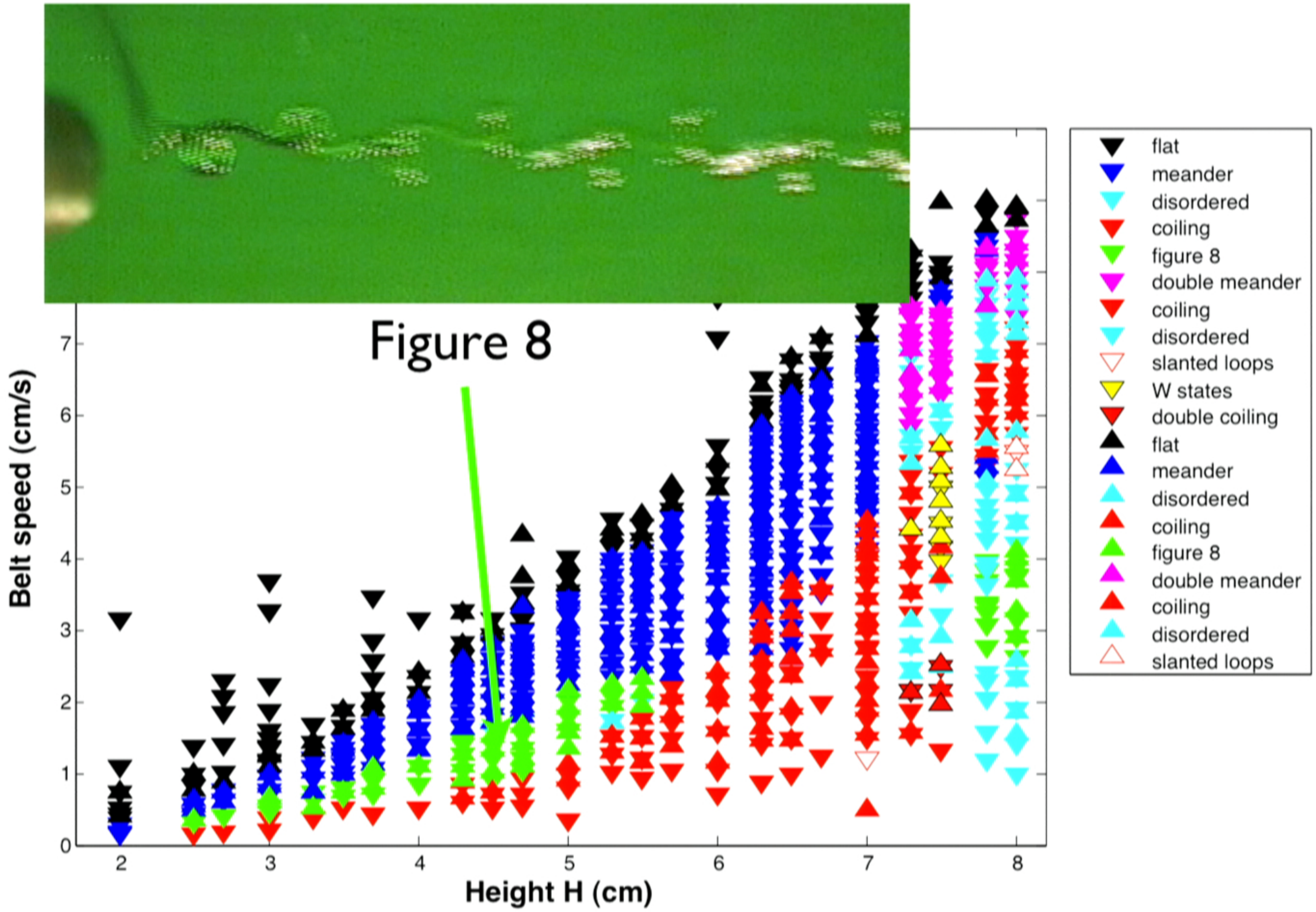
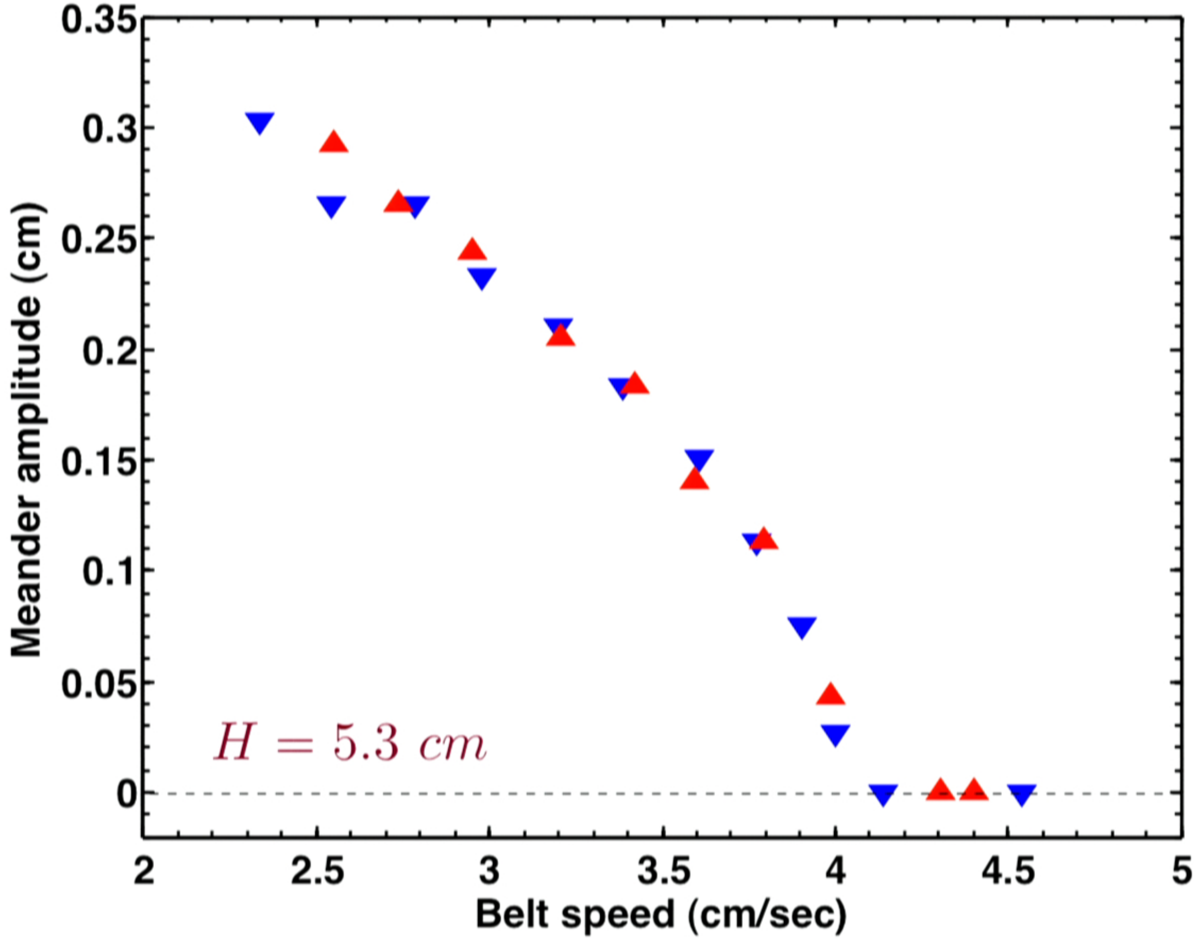
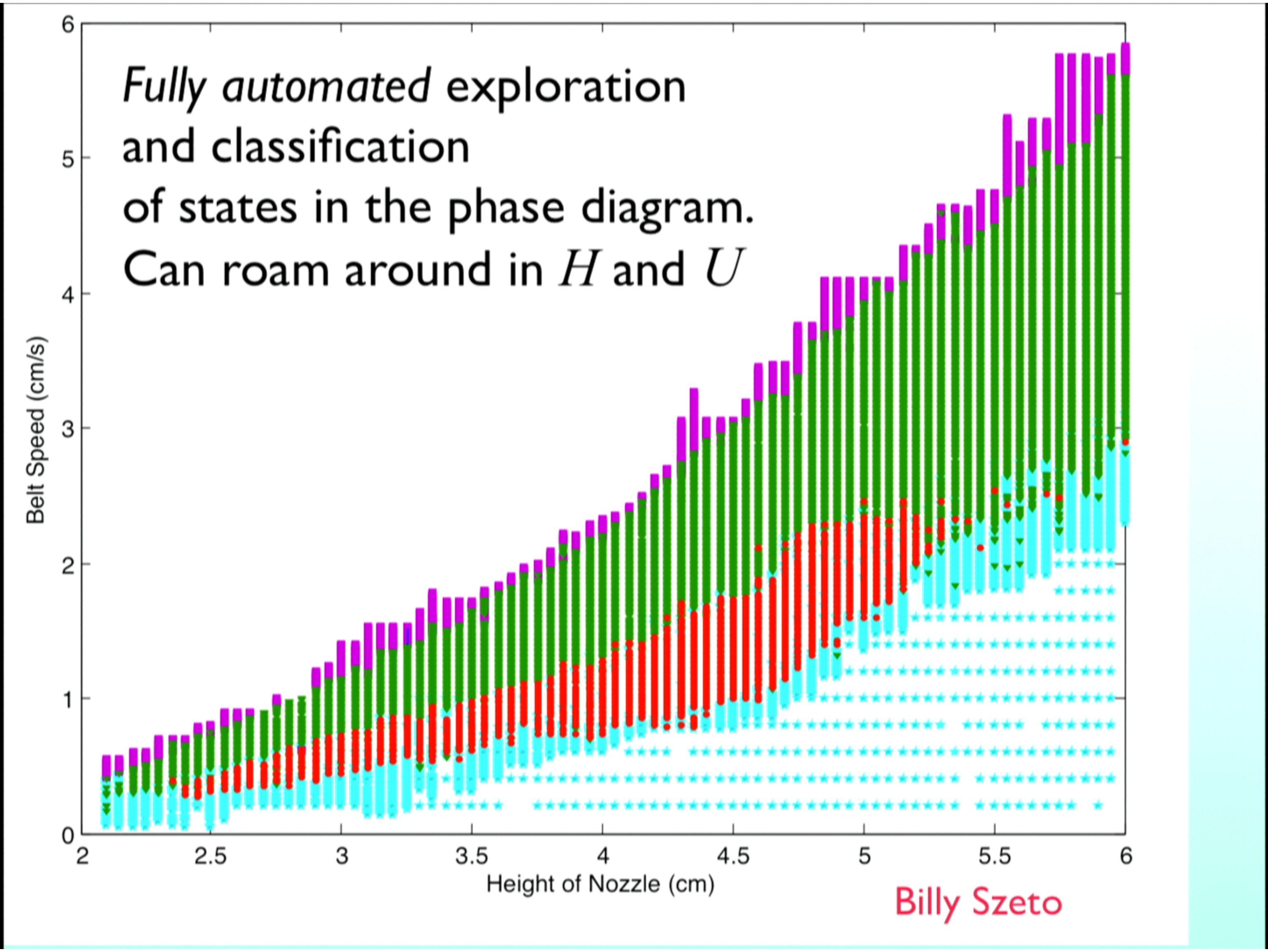


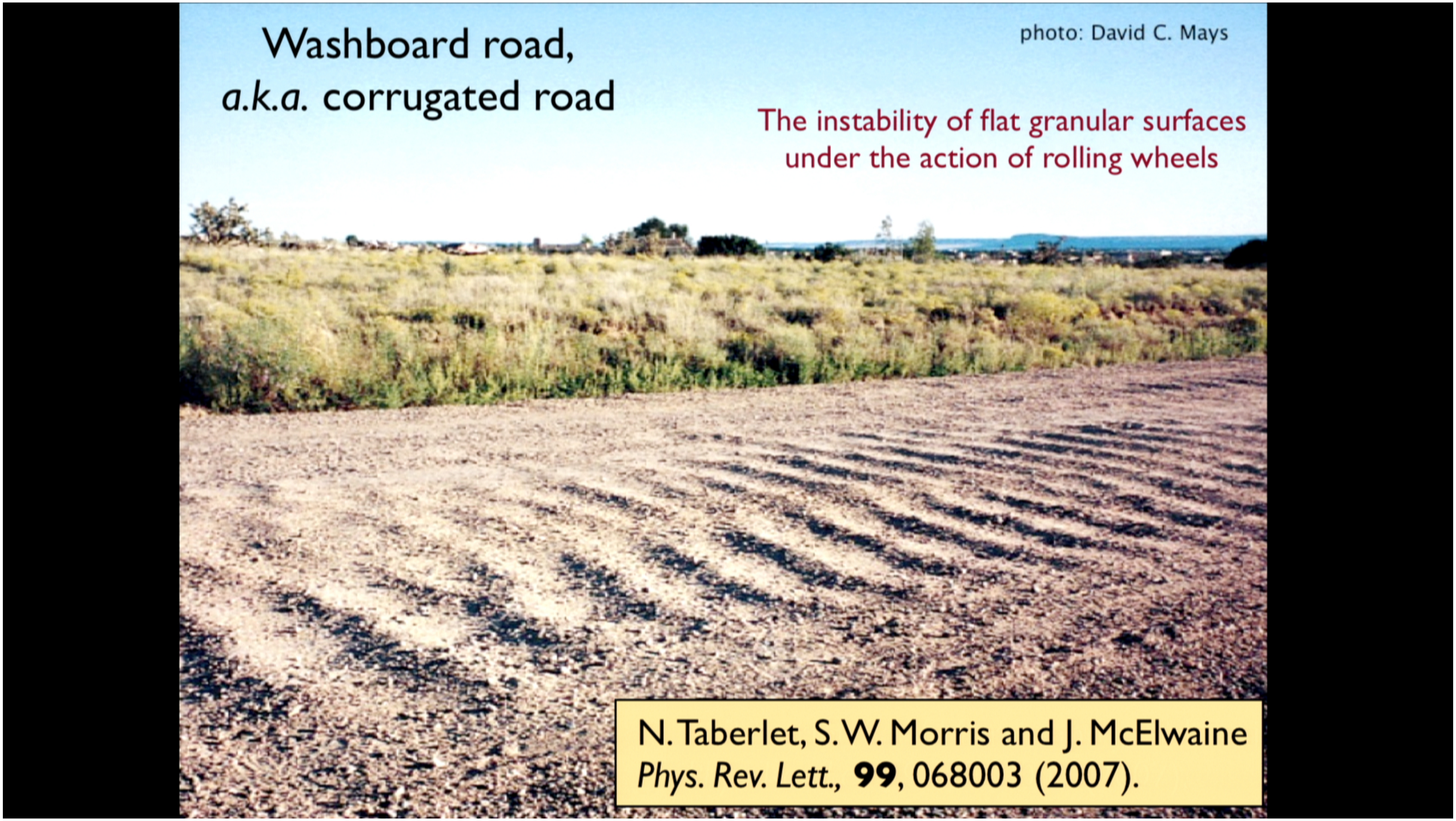
Image and movie by S. Chiu-Webster

Meander amplitude vs. belt speed

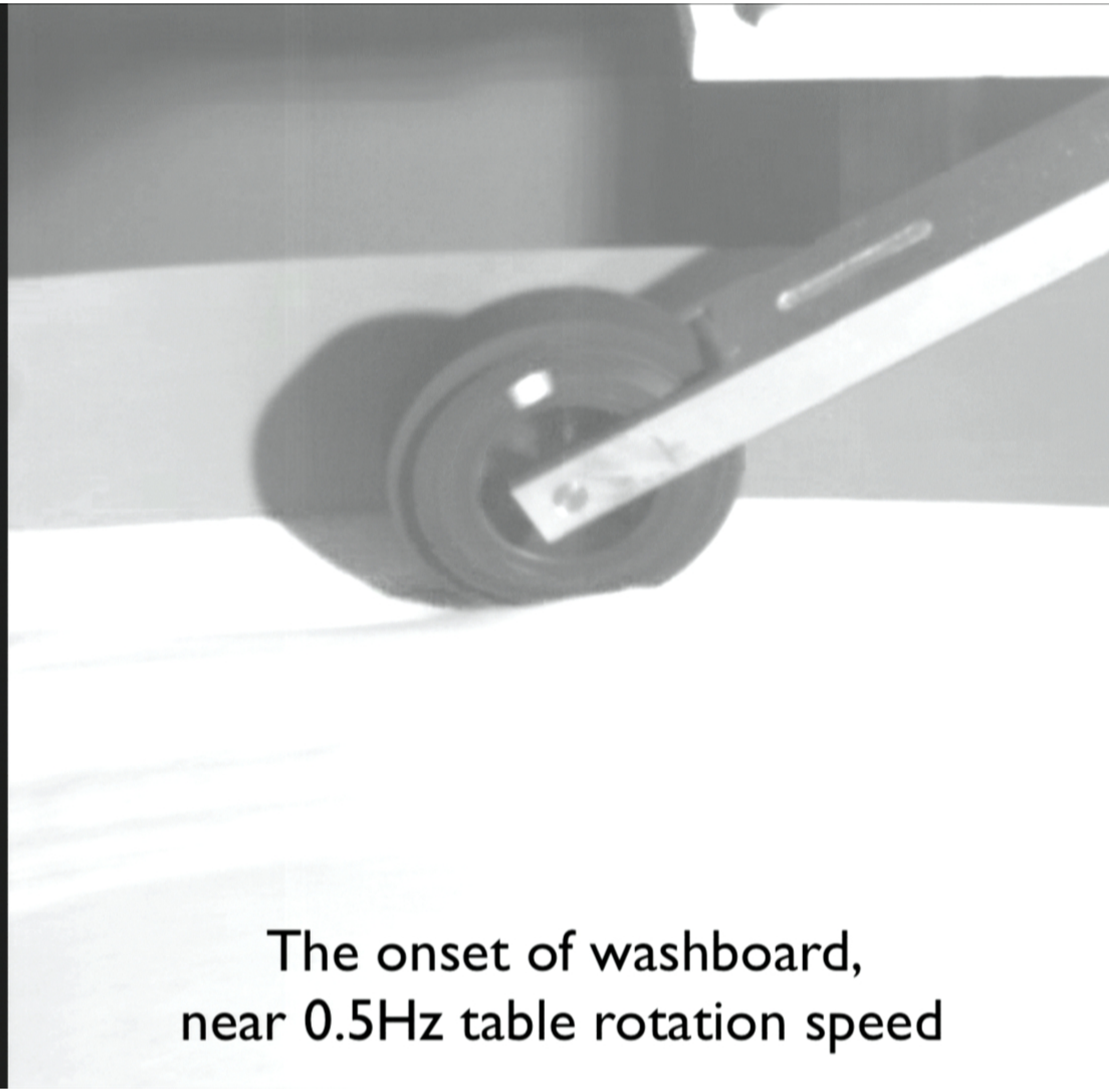


S. W. Morris, J. H. P. Dawes, N. M. Ribe, and J. R. Lister, ***Phys. Rev. E***, 77, 066218 (2008).

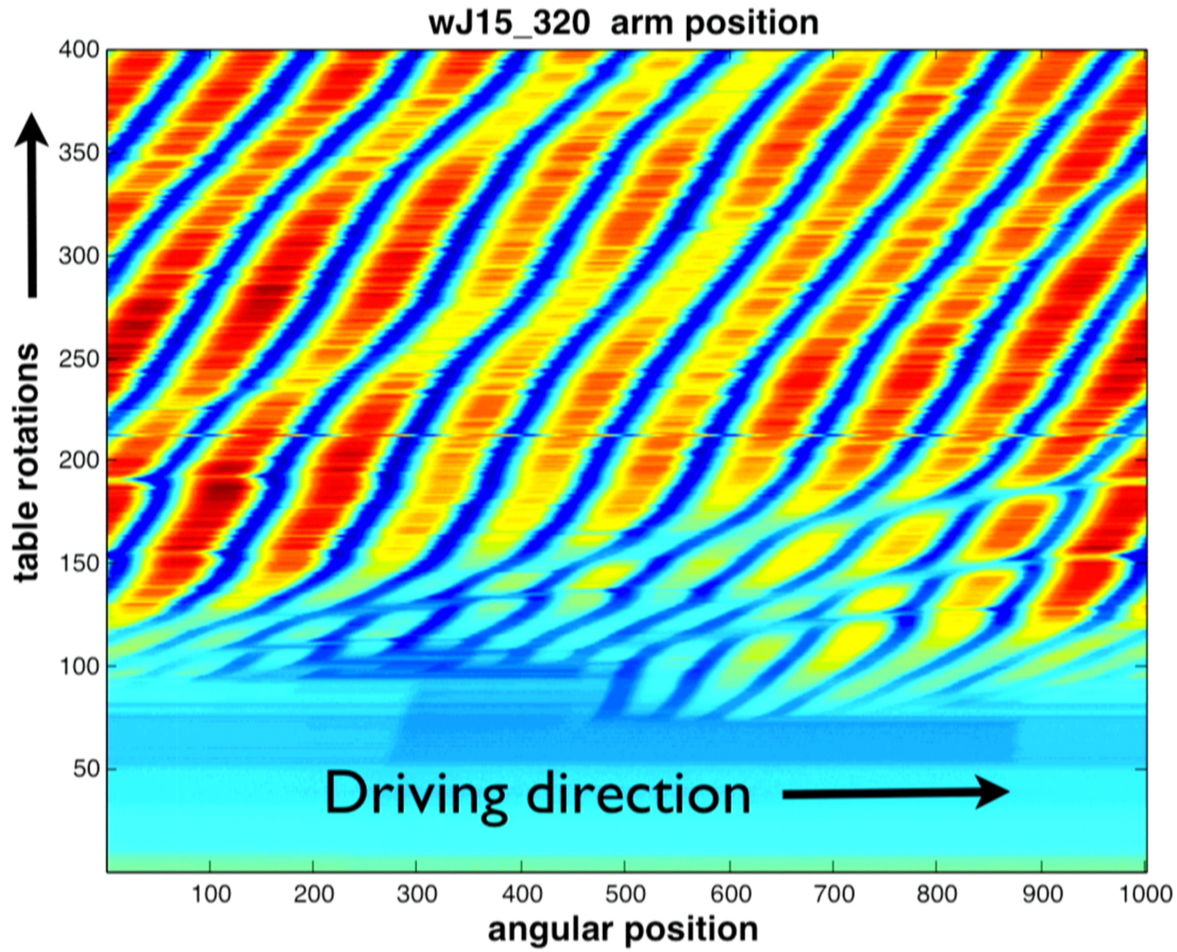

Fully automated exploration
and classification
of states in the phase diagram.
Can roam around in H and U
Belt Speed (cm/s)
0
1
2
3
4
5
6
2
2.5
3
3.5
4
4.5
5
5.5
6
Height of Nozzle (cm)
Billy Szeto


Washboard road,
a.k.a. corrugated road
photo: David C. Mays
The instability of flat granular surfaces
under the action of rolling wheels
N. Taberlet, S. W. Morris and J. McElwaine
Phys. Rev. Lett., 99, 068003 (2007).

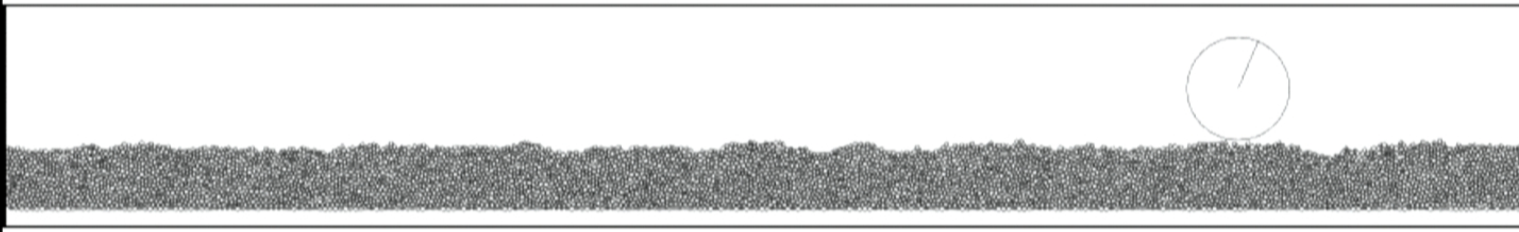

Experiment
Leave the wheel still
and rotate the road!

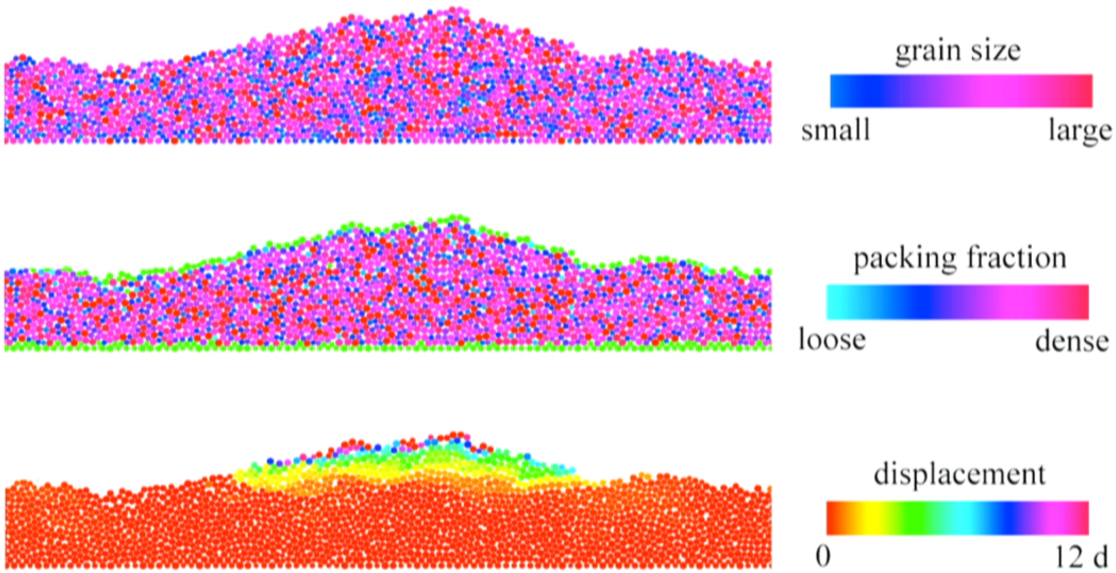

The onset of washboard,
near 0.5Hz table rotation speed

The angle of the arm in spacetime view



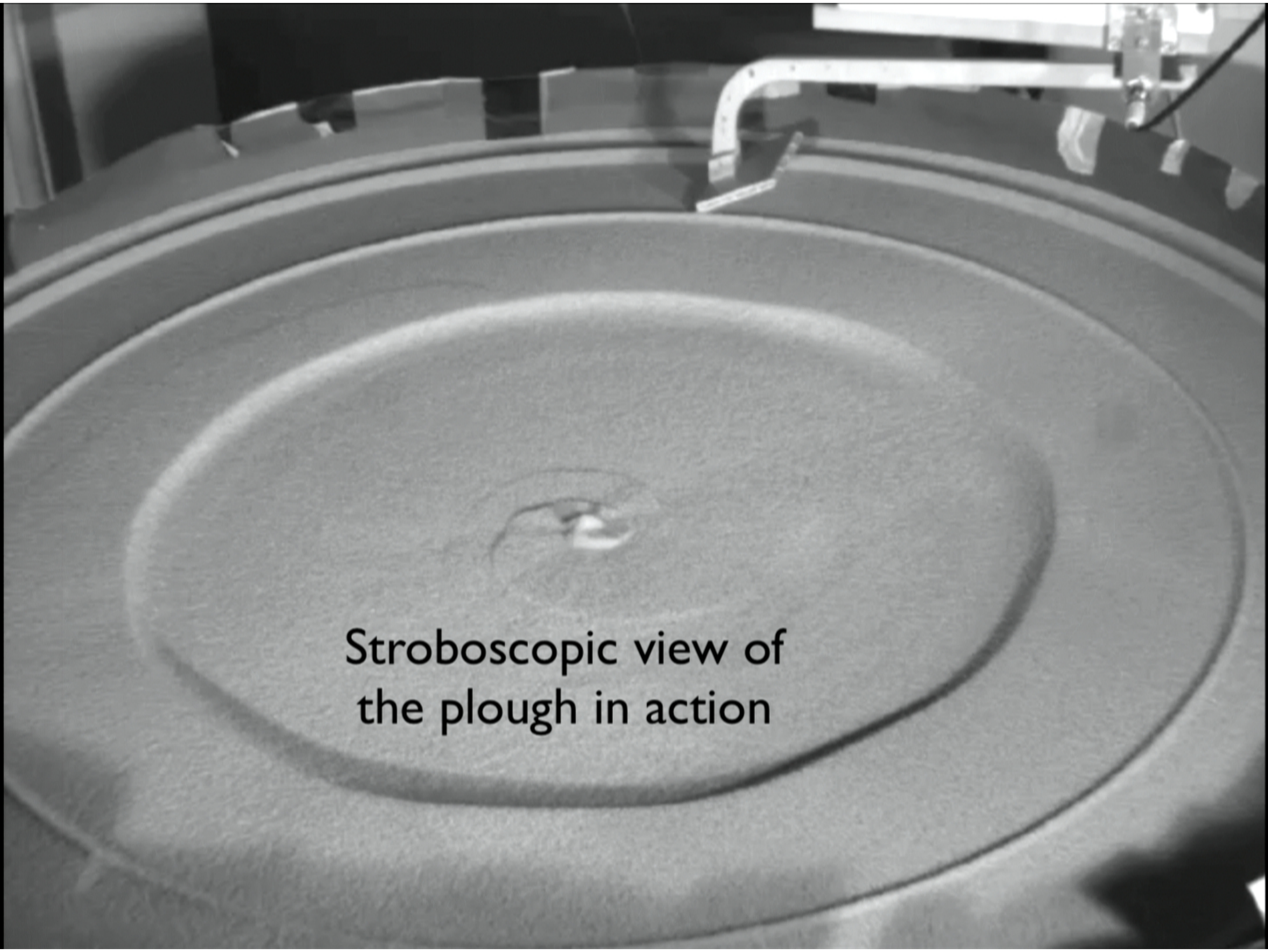
2D soft particle simulations by Nicolas Taberlet





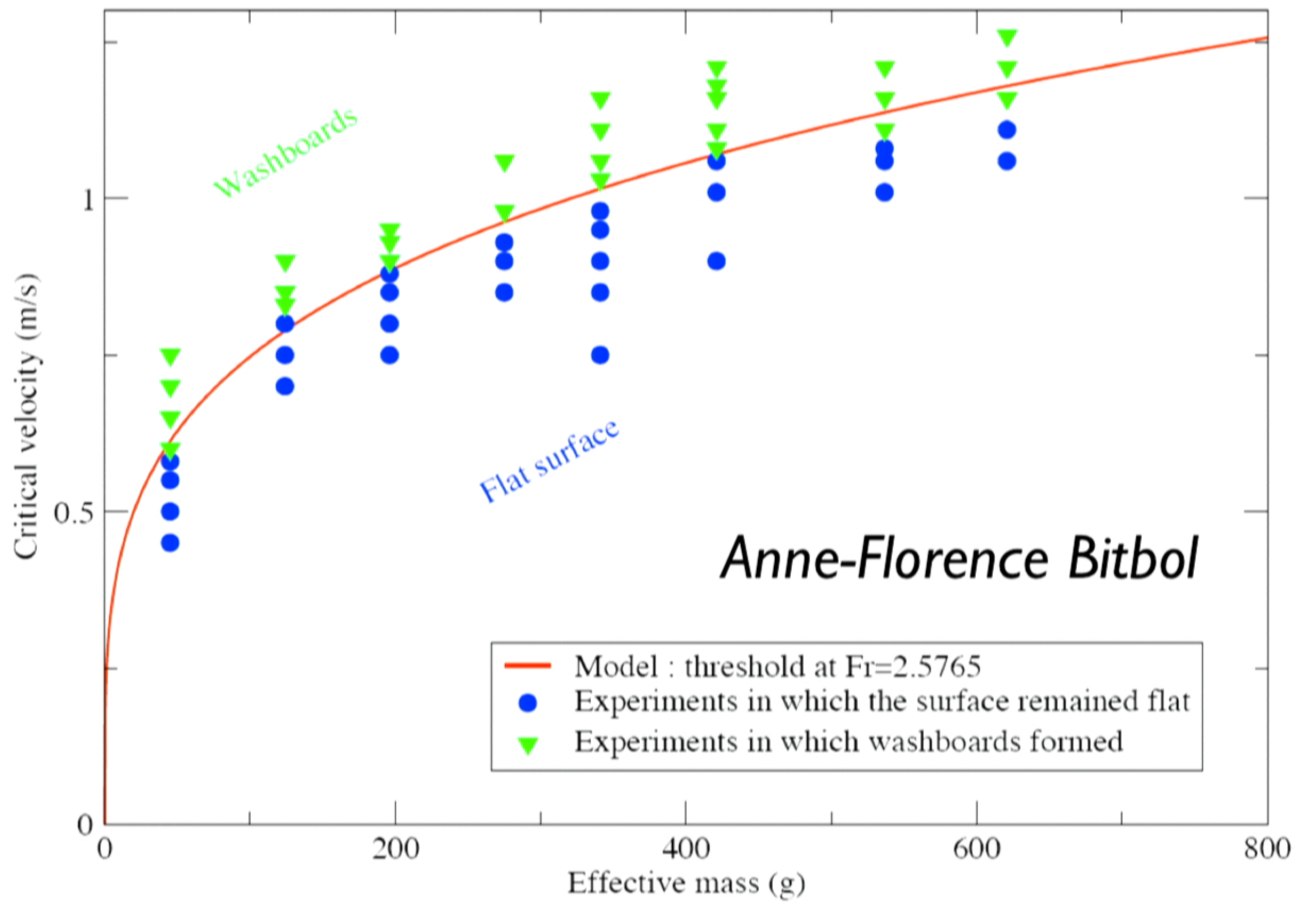
Find that washboard does *not* essentially involve compaction or size segregation, falsifying some models.


The plough: no wheel,
no suspension

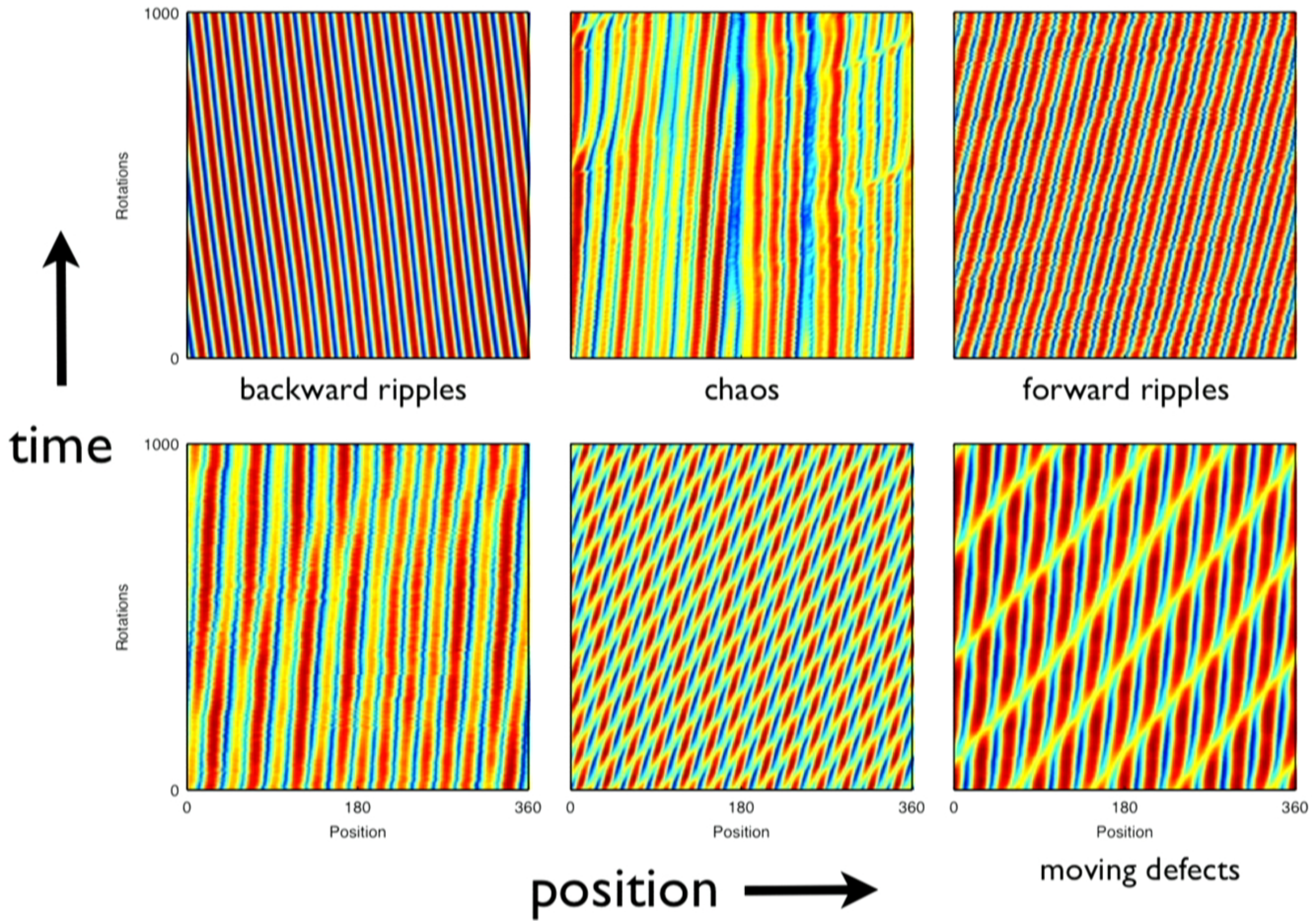

Stroboscopic view of
the plough in action

Scaling theory: Froude number

$$\mathrm{Fr} = \frac{v^2}{g}\sqrt{\frac{\rho w}{m}} \qquad v_c \sim m^{1/4}$$



Other experimental zoology




What is the *ideal* shape of an icicle?

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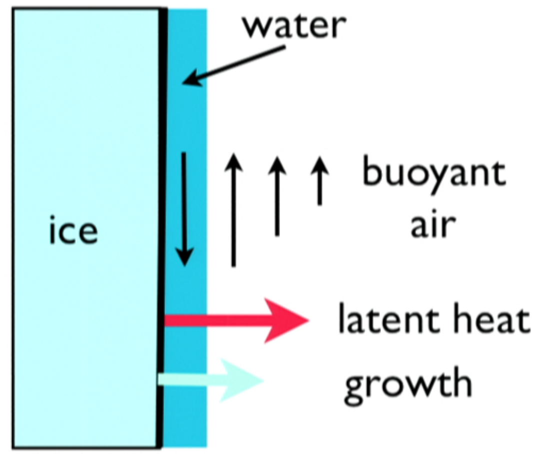
Predicting the emergent shape of an icicle is a non-trivial free-boundary growth problem.

Short, *et al.* derived a nonlinear scaling solution for the ideal icicle shape:

$$\rho = \frac{r}{a} \text{ and } \zeta = \frac{z}{a}$$



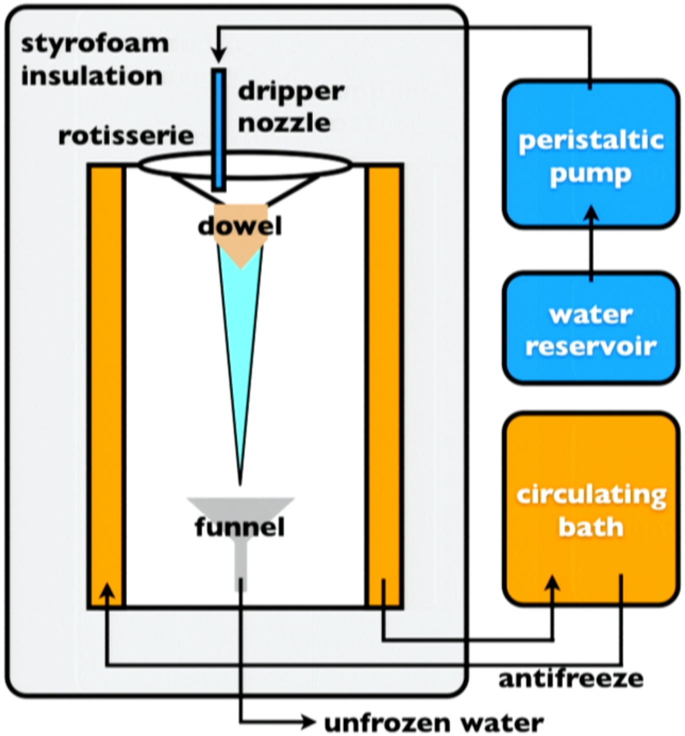
$$\rho(\zeta) = \frac{4}{3}(\zeta^{\frac{1}{2}} + 2)\sqrt{\zeta^{\frac{1}{2}} - 1}$$

Away from the tip: $\rho \sim \zeta^{\frac{3}{4}}$

"All *platonic* icicles have the same shape."

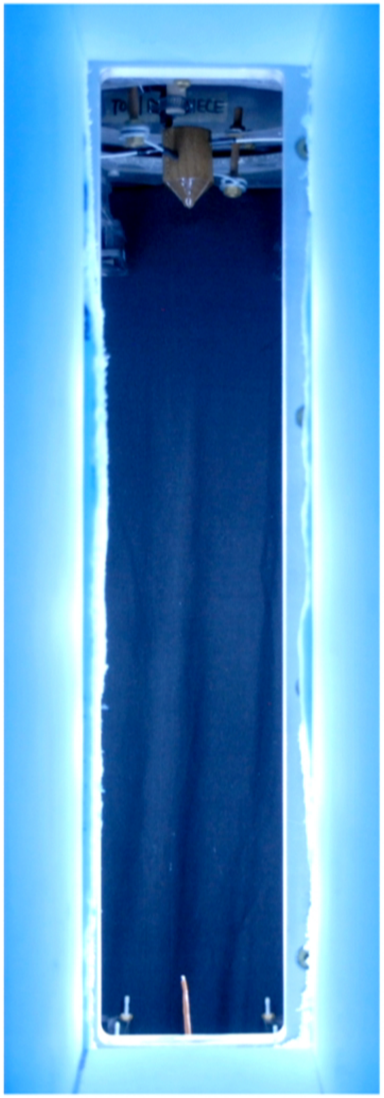
*M. B. Short, J. C. Baygents, R. E. Goldstein, Phys. Fluids, **18**, 083101 (2006).*

The icicle machine



Using time-lapse photography, we can make movies of the icicle's evolving morphology and study the dynamics of their ripples.

1 sec of movie = 10 min (1 rotation / 4 min)



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Fitting the shape

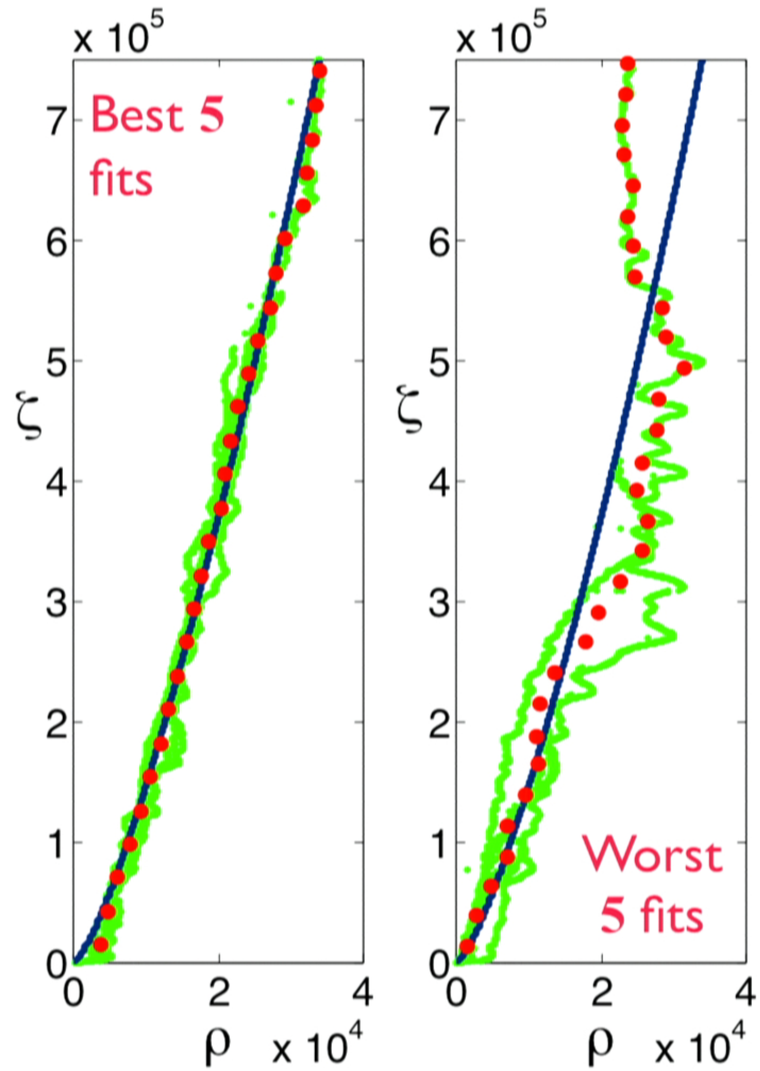
To extract the profiles of lab-grown icicles, we apply edge detection to the images.

For each icicle, the profile $r(z)$ was fit to the theoretical shape:

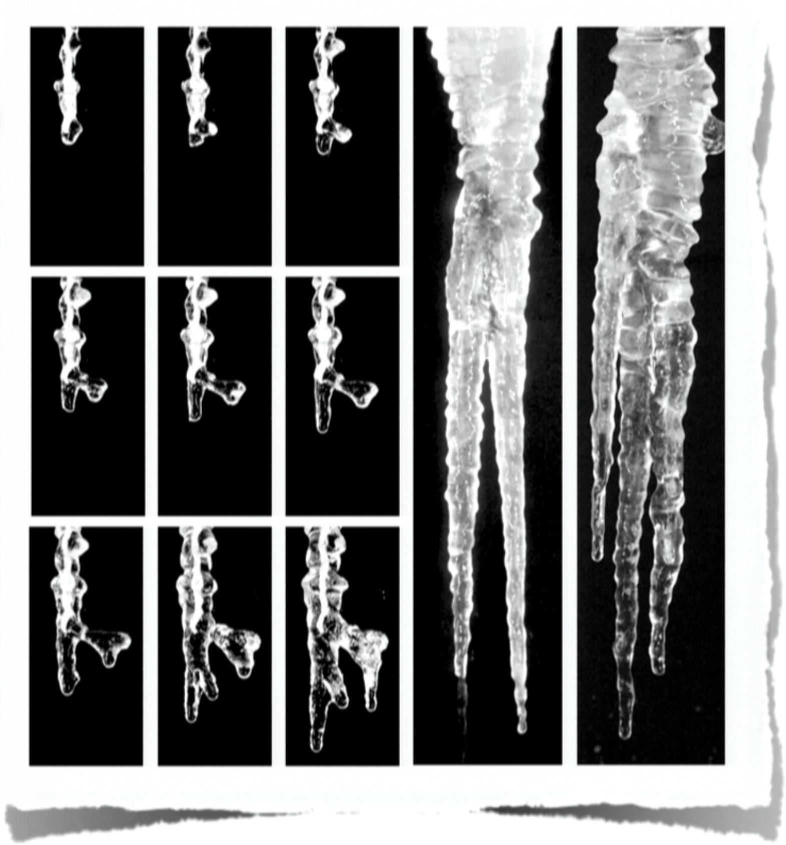
$$r = a\left(\frac{4}{3}\left[\left(\frac{z}{a}\right)^{\frac{1}{2}} + 2\right]\sqrt{\left(\frac{z}{a}\right)^{\frac{1}{2}} - 1}\right)$$

via a least-squares analysis to get the best-fit scaling factor a.

For over 100 icicles, we find that *some* icicles fit the theory very well, while others *do not*.



Air motion matters



Icicles tend to form multiple tips
if air is *not* stirred.

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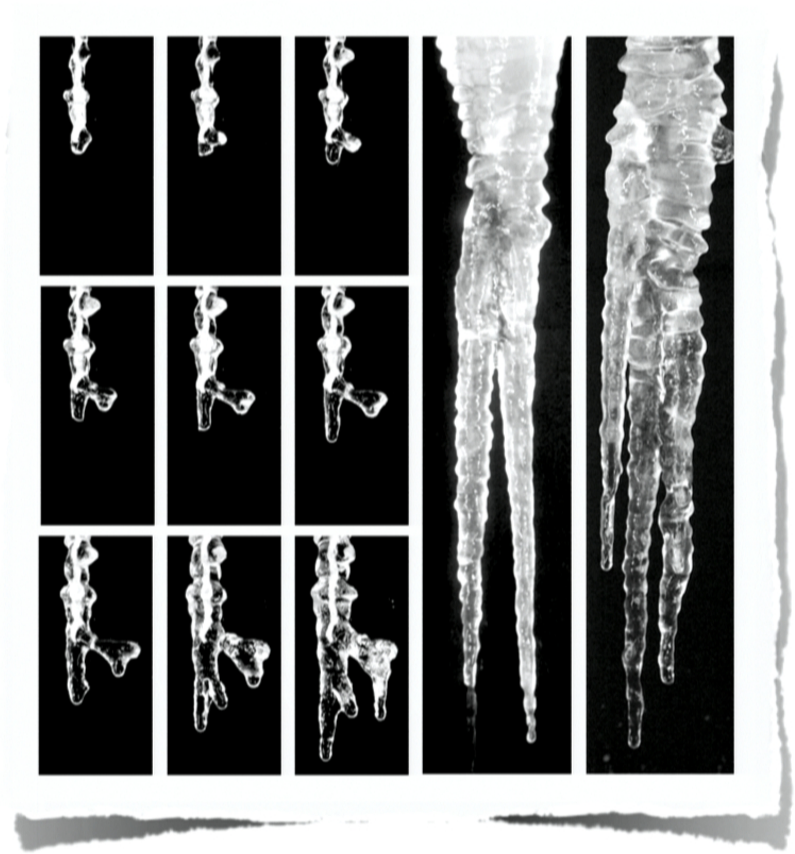

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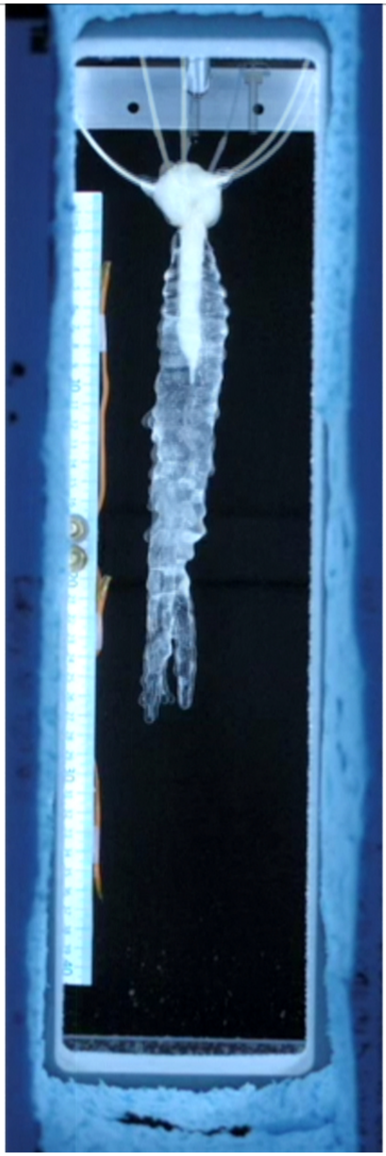


Ripple instability

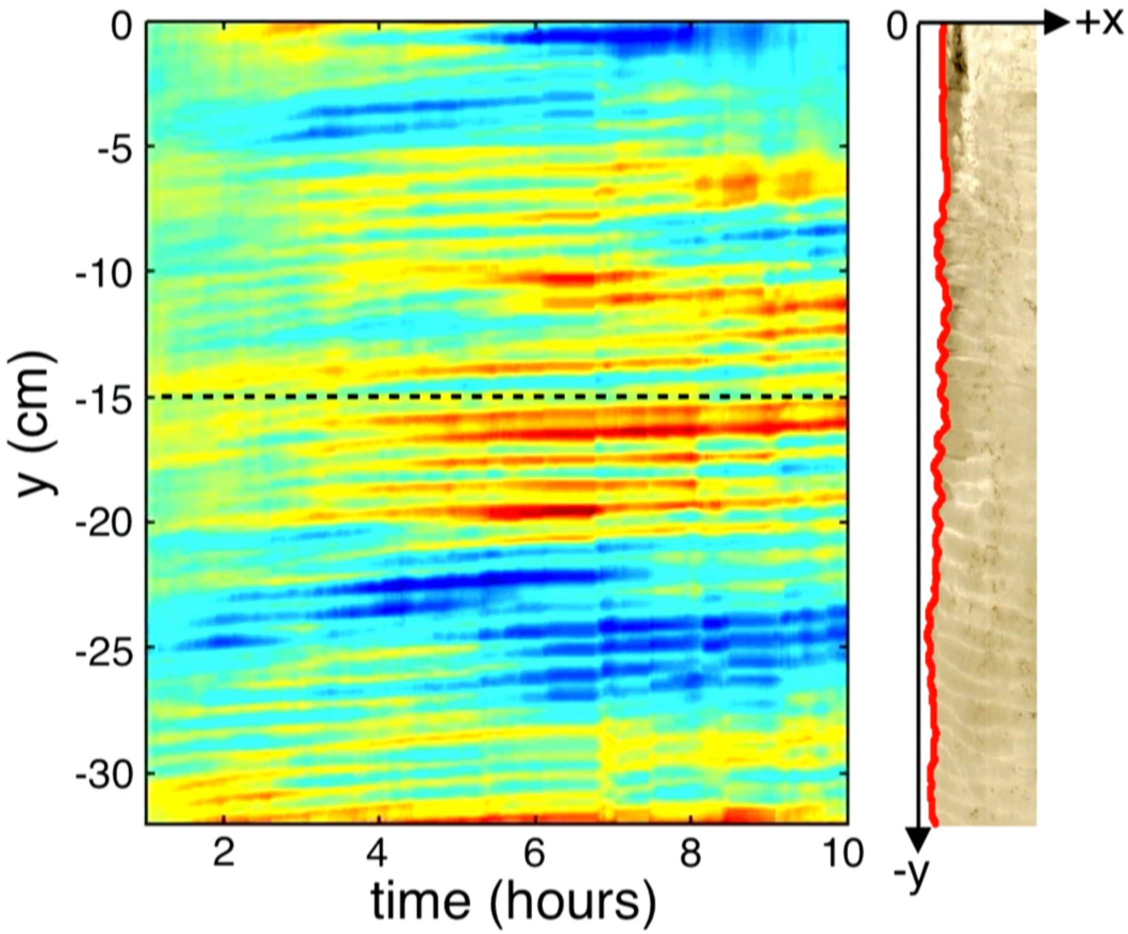
"Michelin Man" ring-like ridges are often seen on the surface of icicles. Not accounted for in shape theory.

Linear stability analysis including surface tension predicts ripples move *up* the icicle.

K. Ueno, Phys. Fluids **19**, 093602 (2007).

Ripple motion

Track ripple motion using edge detection.
Indeed, ripples move *up* slightly during growth.



Conclusion: Motivation?

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***Aesthetic**: The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living.- Henri Poincaré*

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Applications?

Conclusion: Motivation?

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Applications?

What is the ontological status of emergent "order parameter physics"?

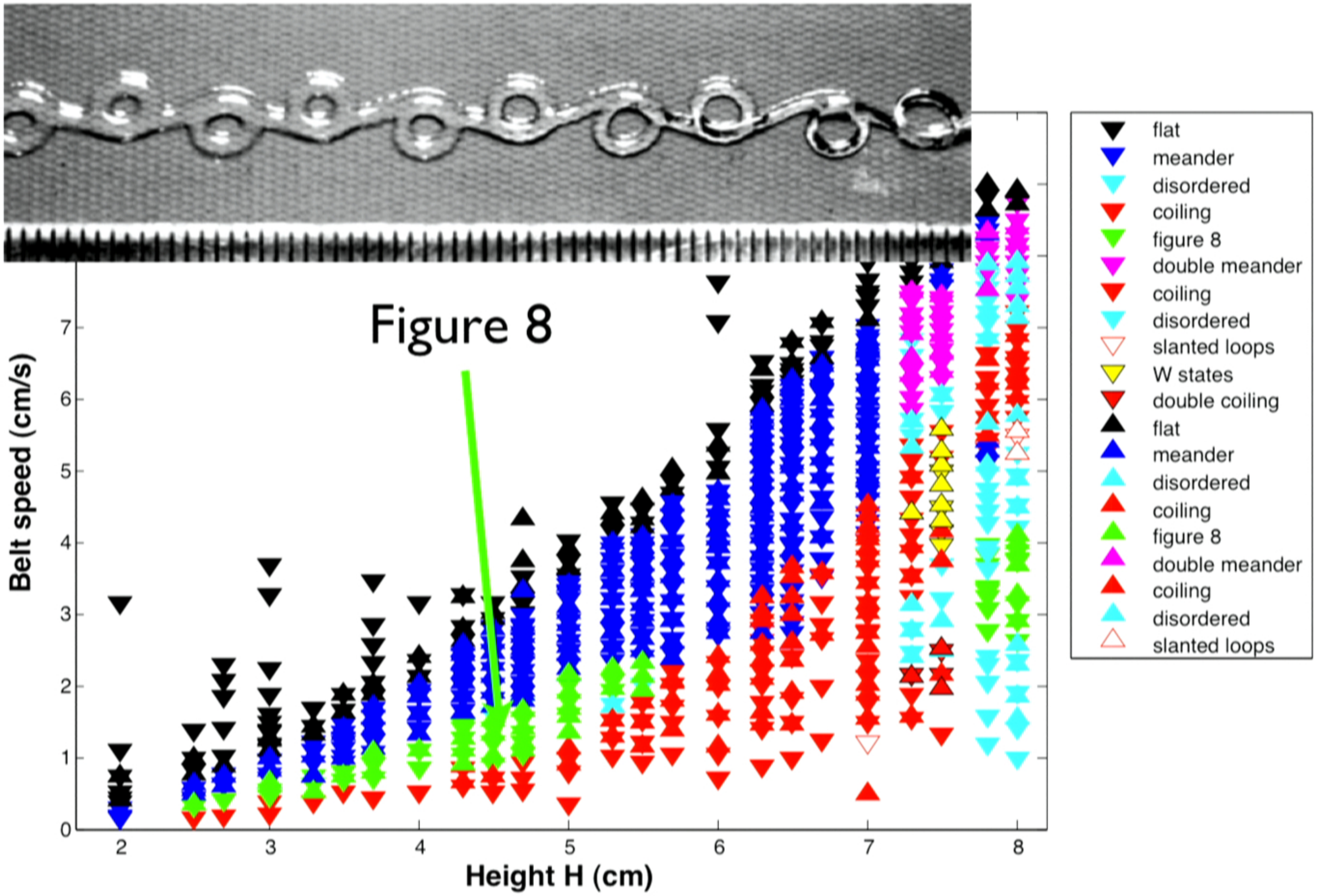

Image and movie by S. Chiu-Webster