Why is the river not straight?

Stability is key,
not *optimality.*


Namibian desert dunes
Where do these length scales come from?
10 cm

Permafrost

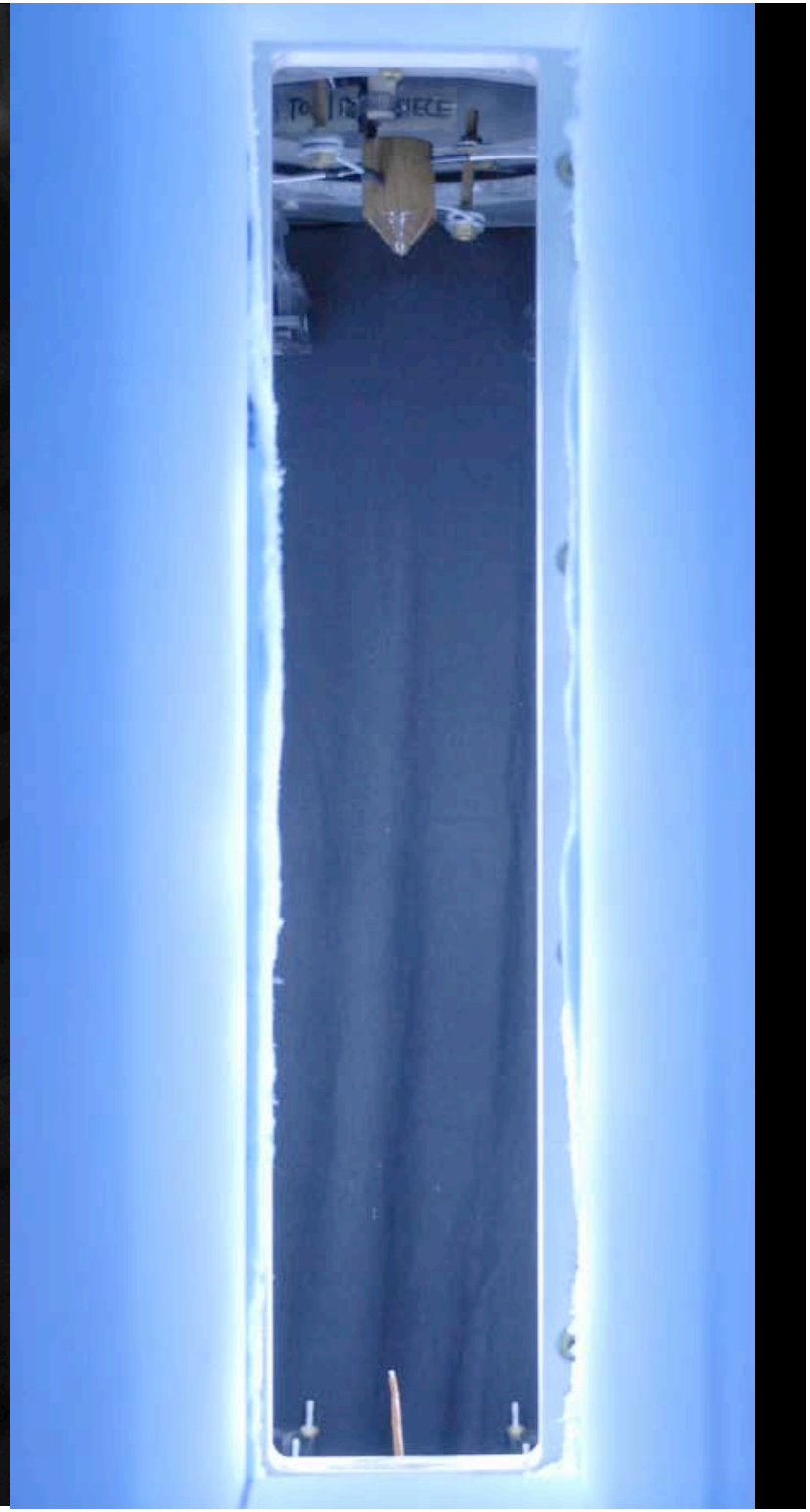
Sorted stone stripes

Stone circles

Beach cusps

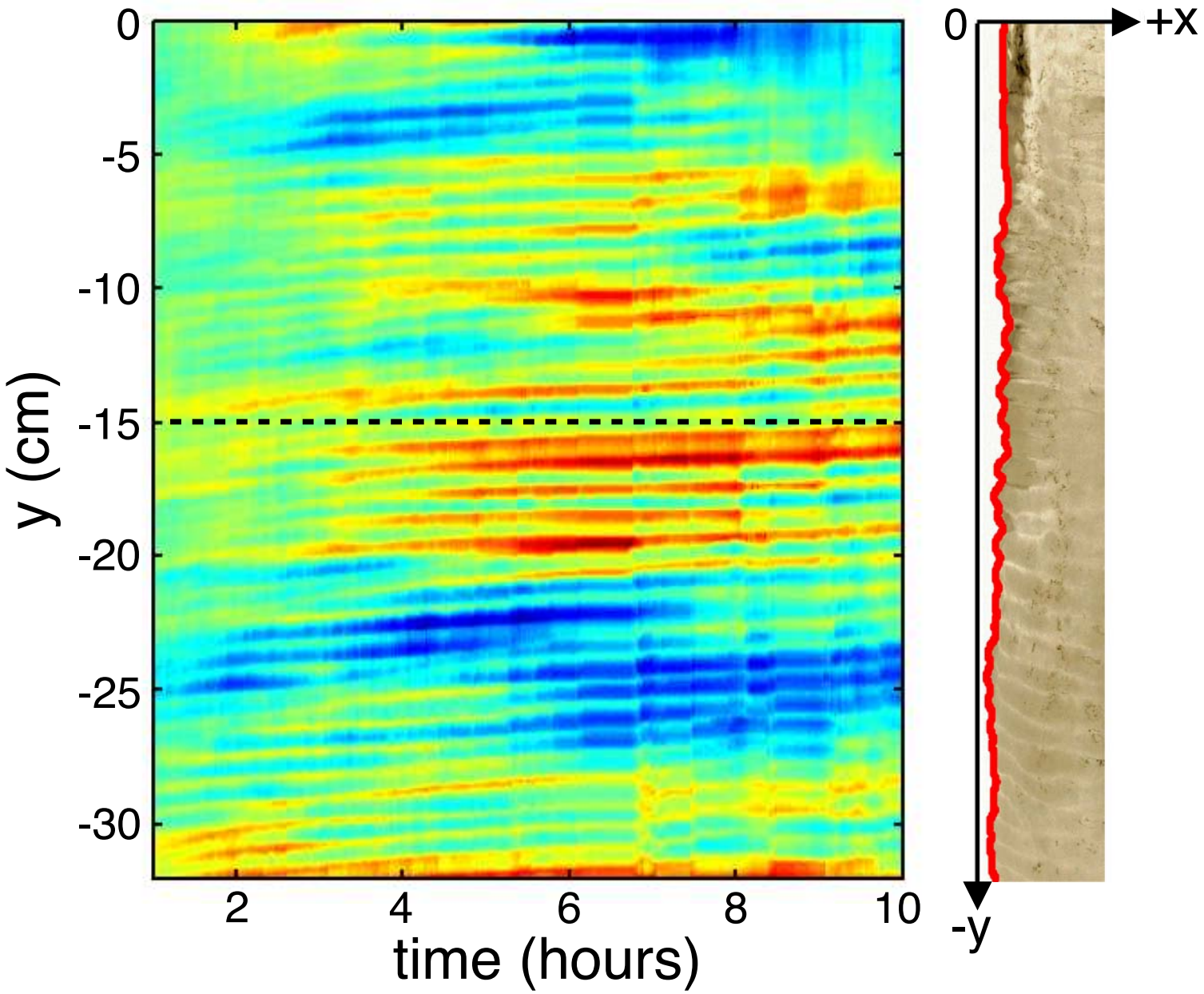

Beach cusps
with size
segregation

the shapes
of icicles



Ripples on icicles

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

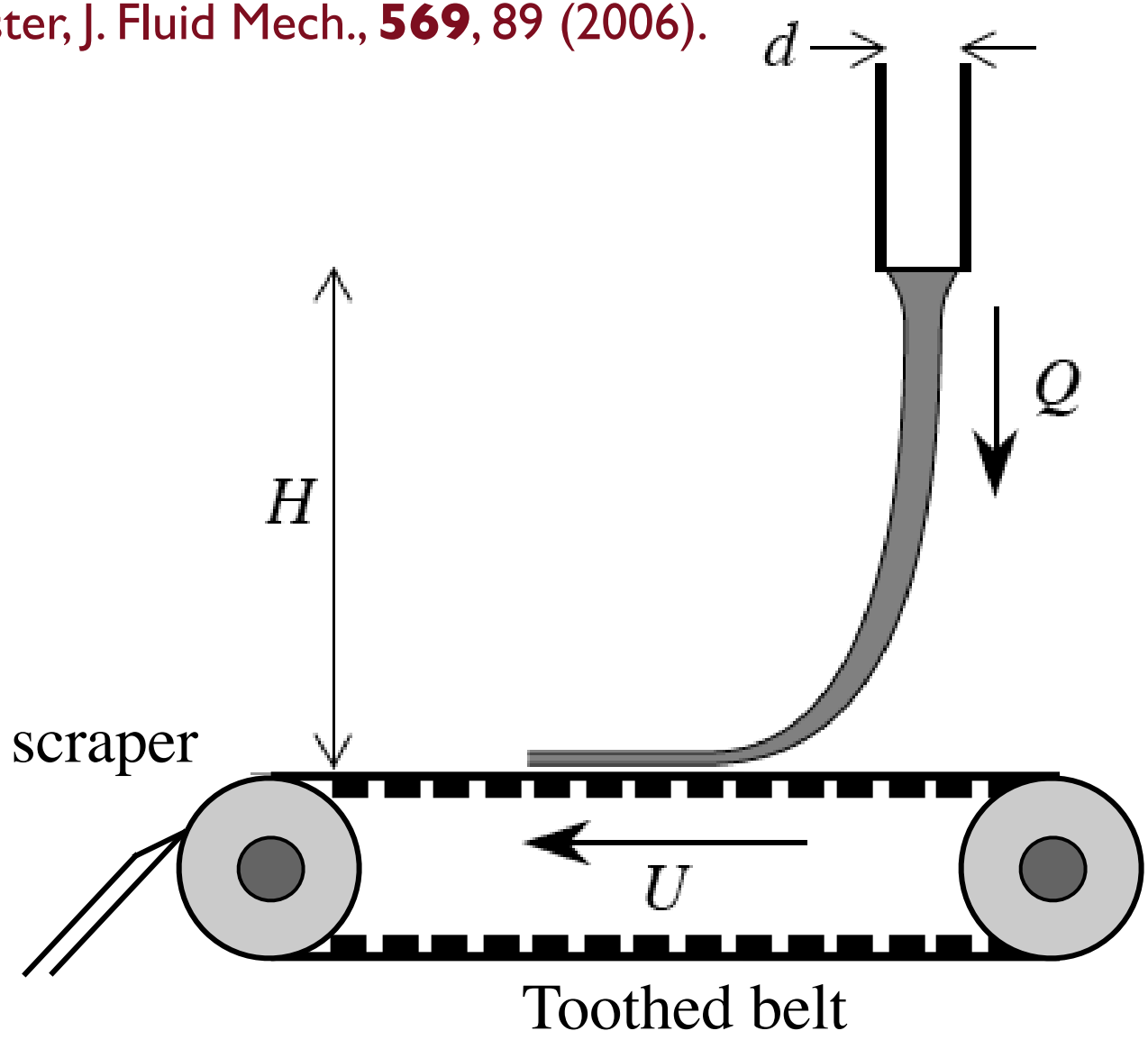


The Fluid Mechanical Sewing Machine

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

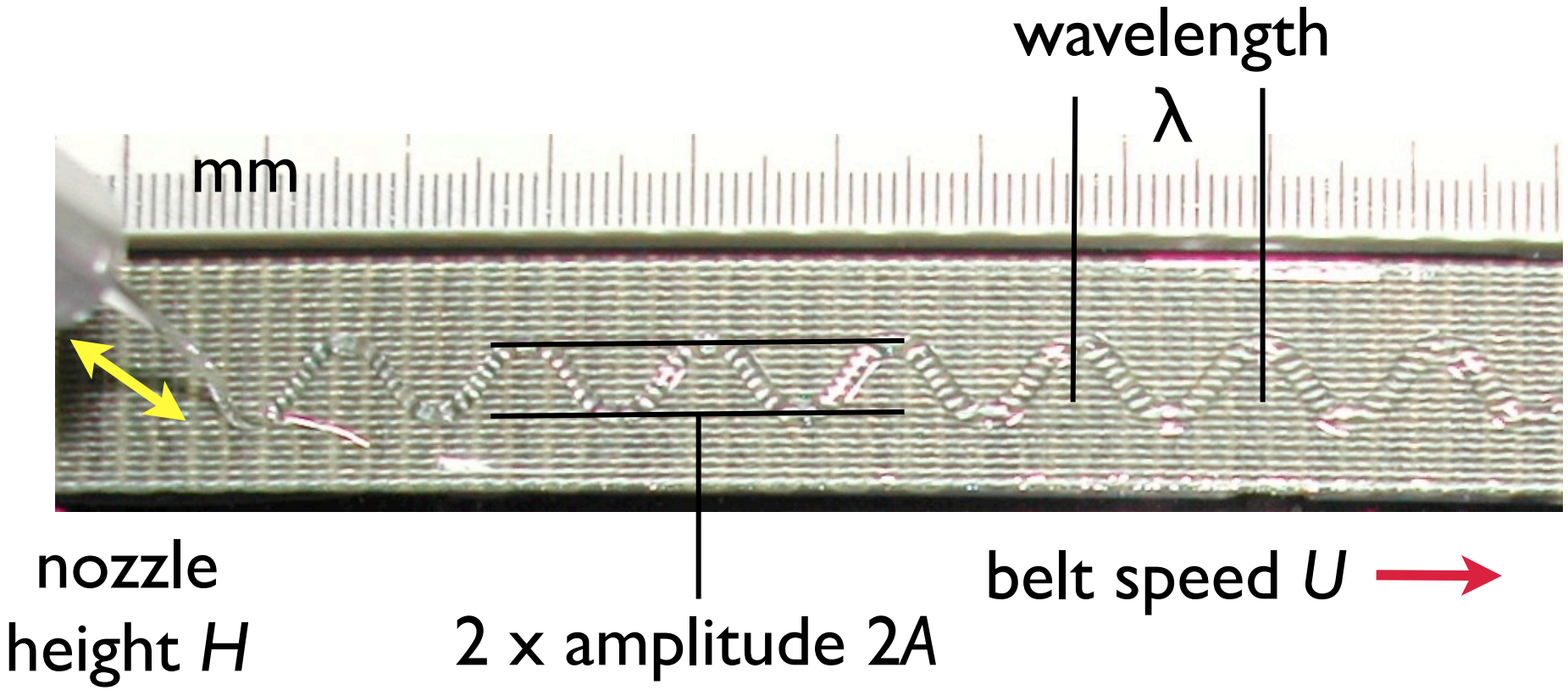
Control parameters:

H and U



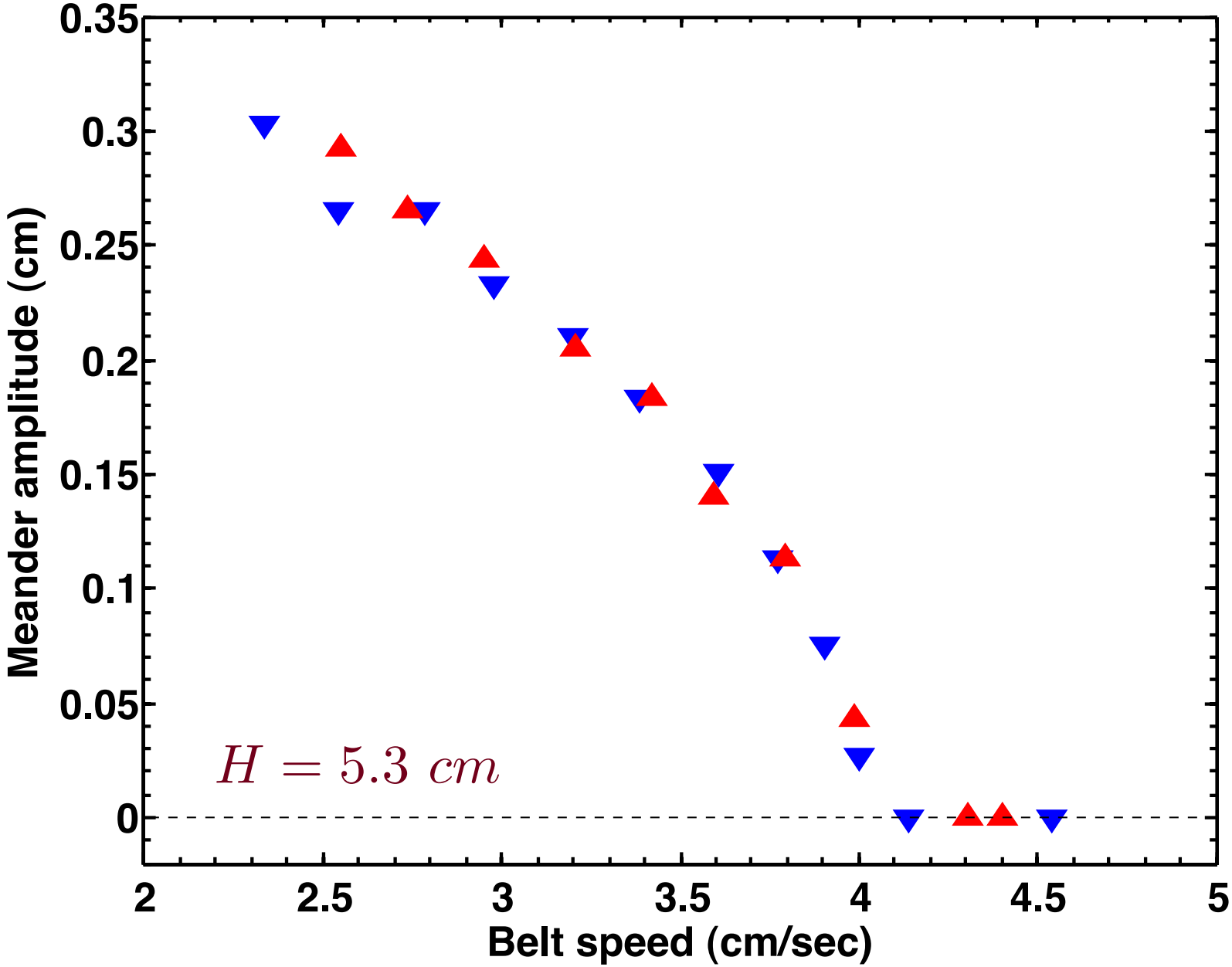
Focus on the initial transition to meandering: what sort of bifurcation is it?

Measuring λ and amplitude as a function of belt speed



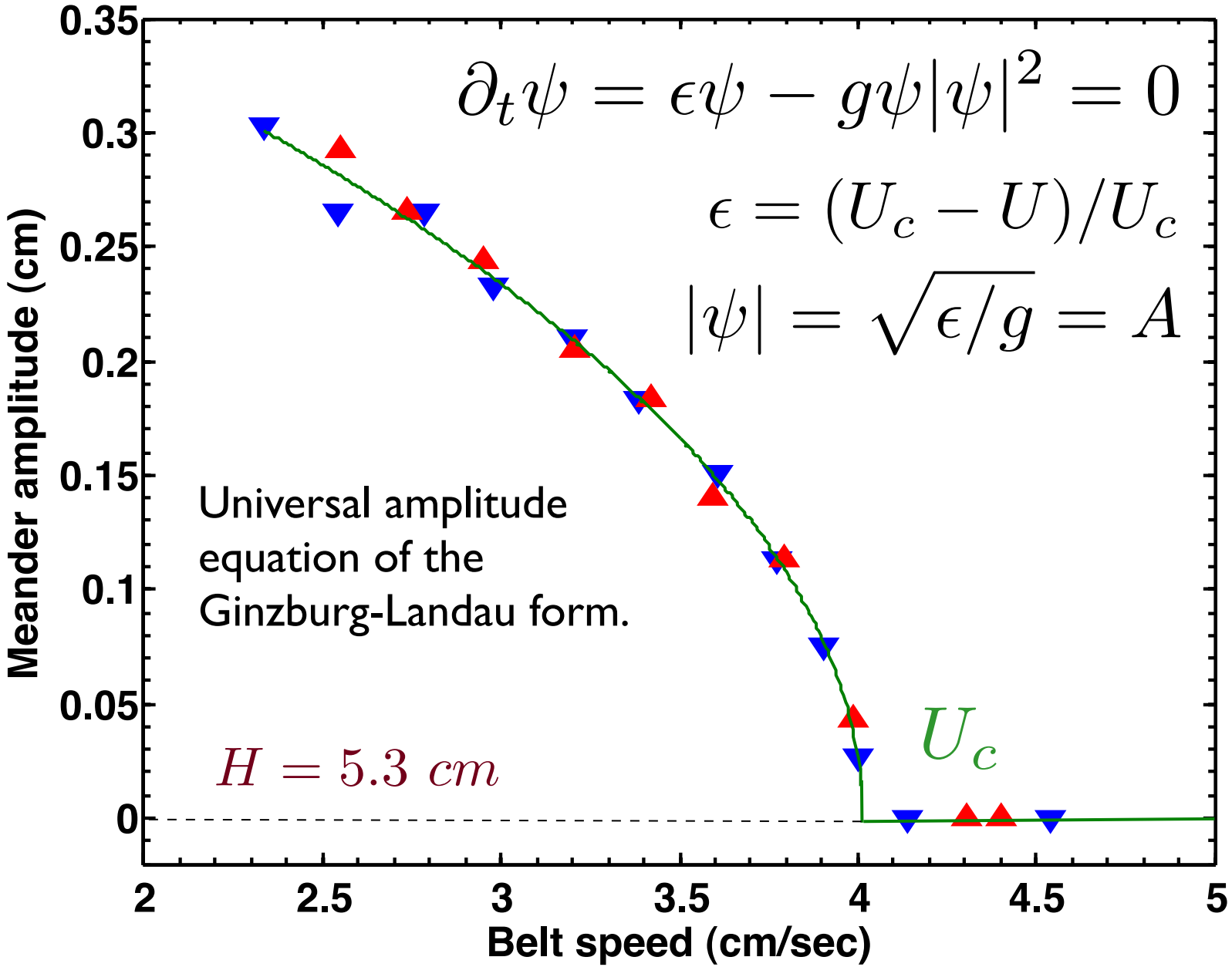
S. W. Morris, J. H. P. Dawes, N. M. Ribe, and J. R. Lister, ***Phys. Rev. E***, 77, 066218 (2008).

Meander amplitude vs. belt speed

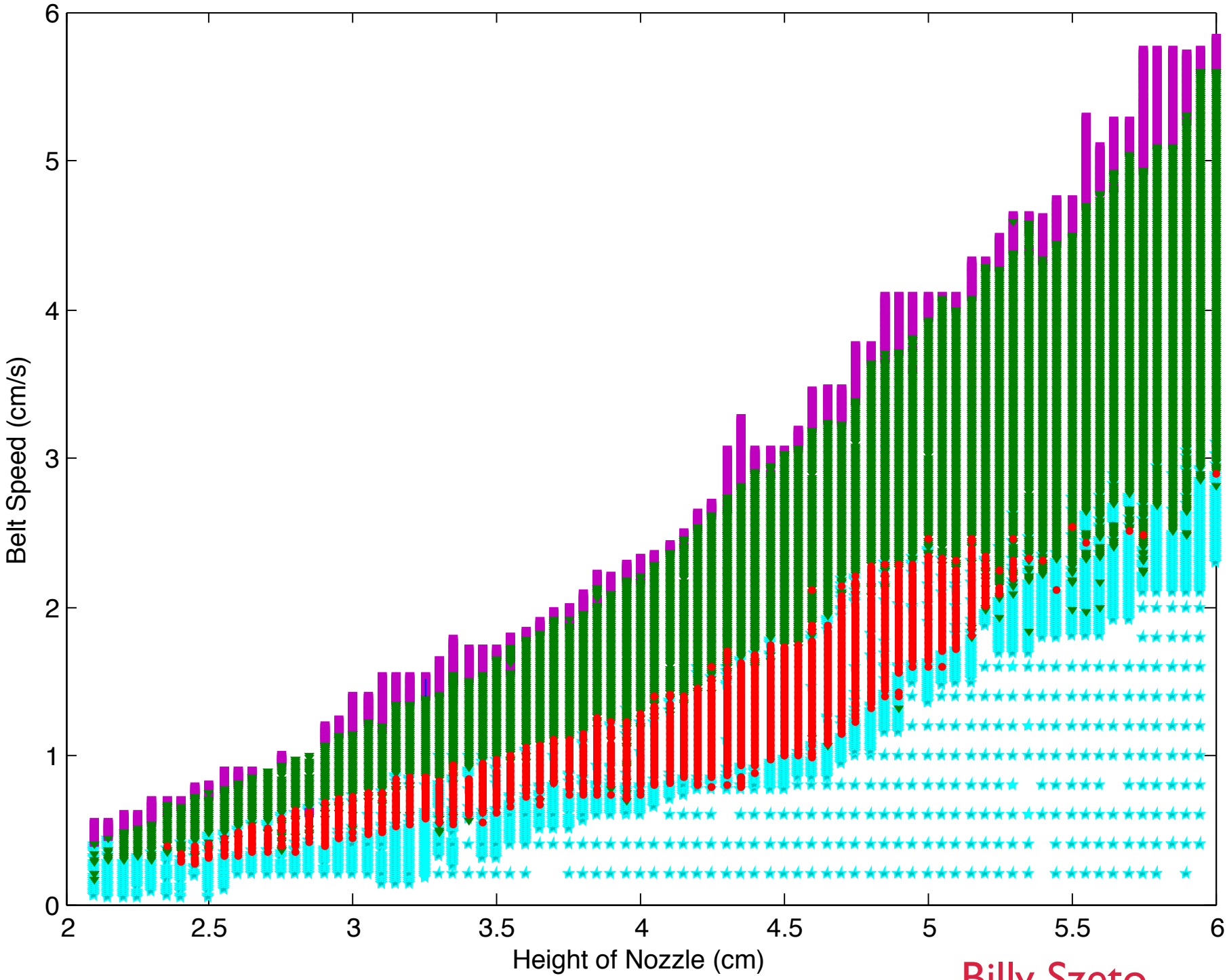


S. W. Morris, J. H. P. Dawes, N. M. Ribe, and J. R. Lister, ***Phys. Rev. E***, 77, 066218 (2008).

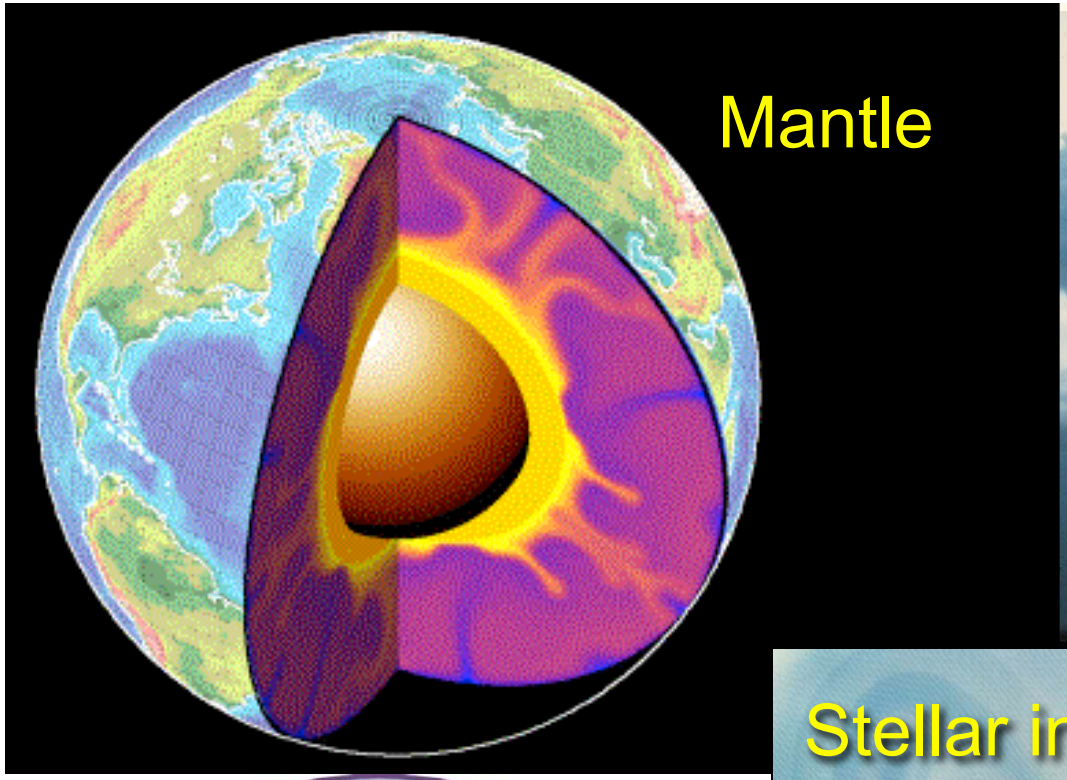
Meander amplitude vs. belt speed



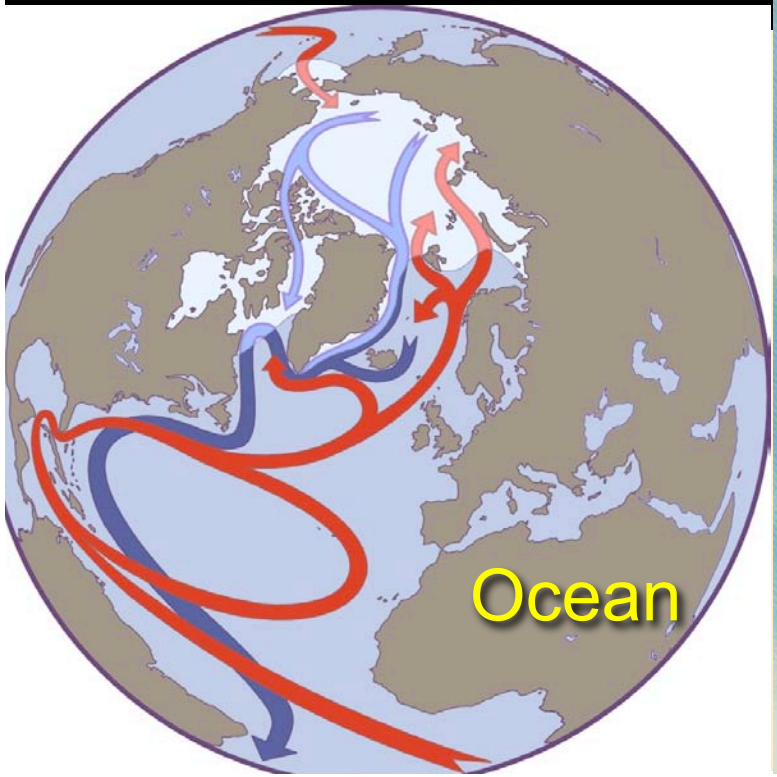
S. W. Morris, J. H. P. Dawes, N. M. Ribe, and J. R. Lister, ***Phys. Rev. E***, 77, 066218 (2008).

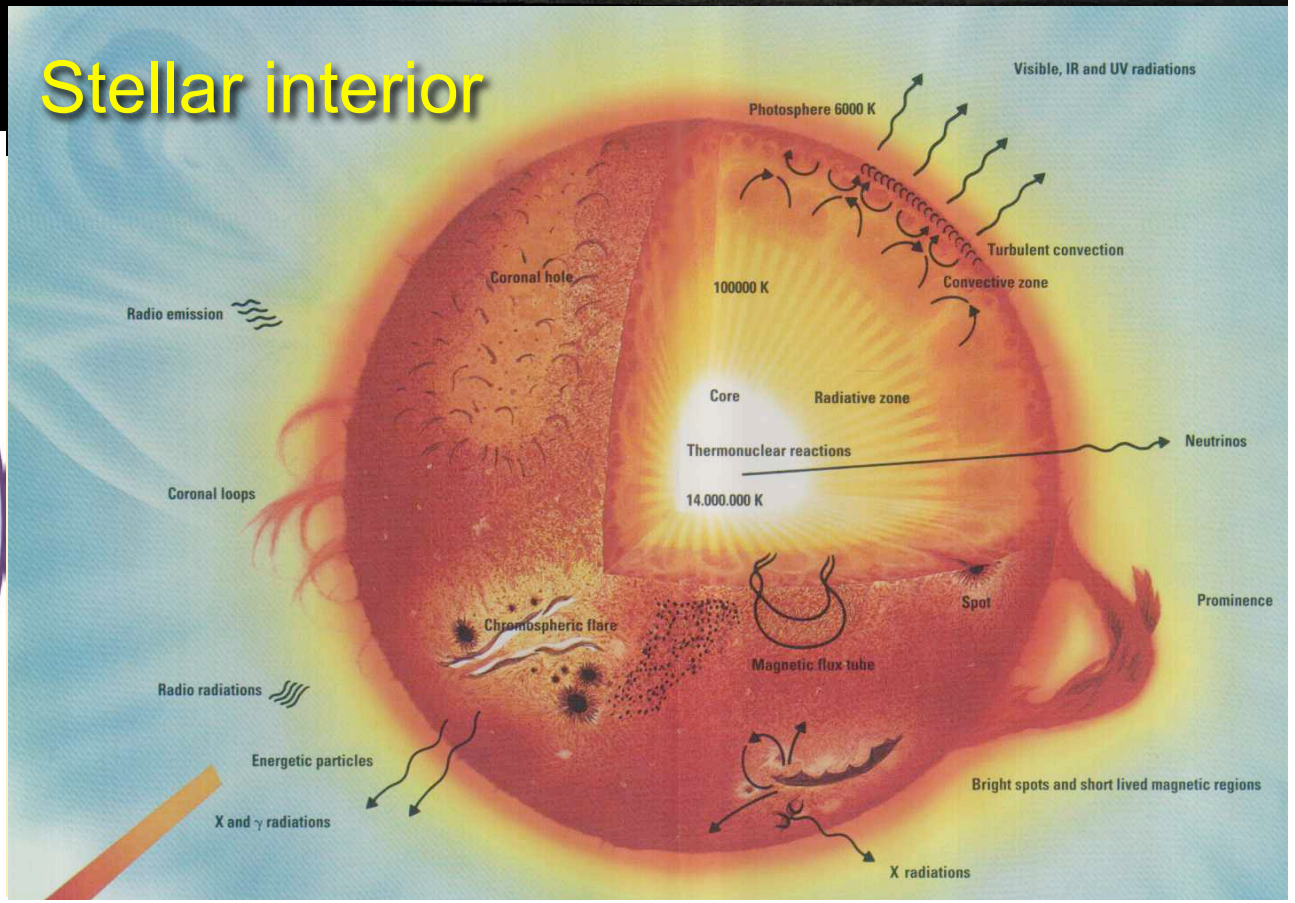


Billy Szeto


Mantle

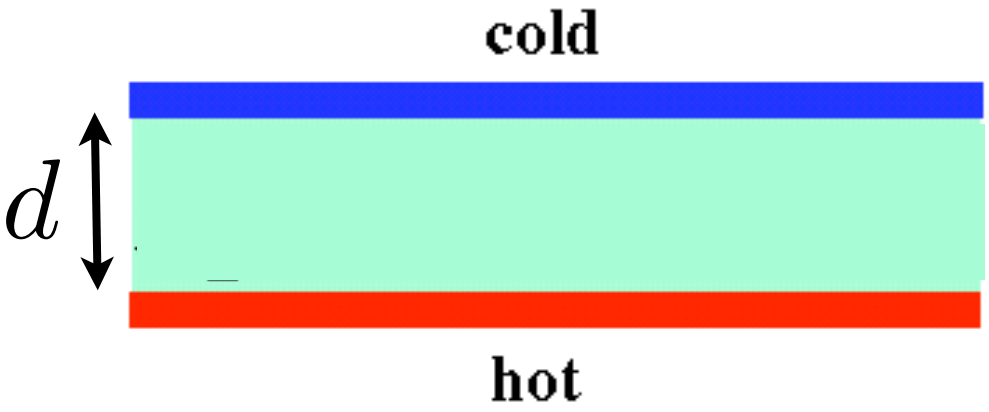

Atmosphere
Convection


Ocean


Stellar interior
Visible, IR and UV radiations
Photosphere 6000 K
Turbulent convection
Convective zone
Coronal hole
100000 K
Radio emission
Core
Radiative zone
Thermonuclear reactions
Neutrinos
14.000.000 K
Coronal loops
Spot
Prominence
Chromospheric flare
Magnetic flux tube
Radio radiations
Energetic particles
Bright spots and short lived magnetic regions
X and γ radiations
X radiations

The Paradigm Case: Rayleigh-Bénard Convection

Studied for over 100 years



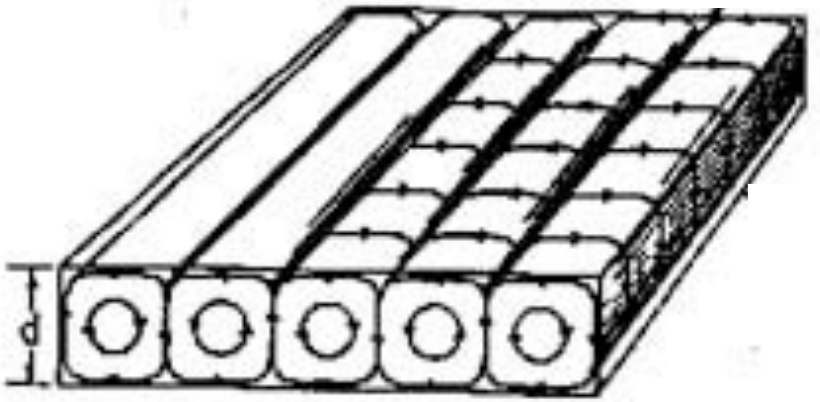
Rayleigh number

$$R = \frac{\alpha g d^3}{\kappa \nu} \Delta T > 1708$$

Onset of convection when $\Delta T > \Delta T_c$

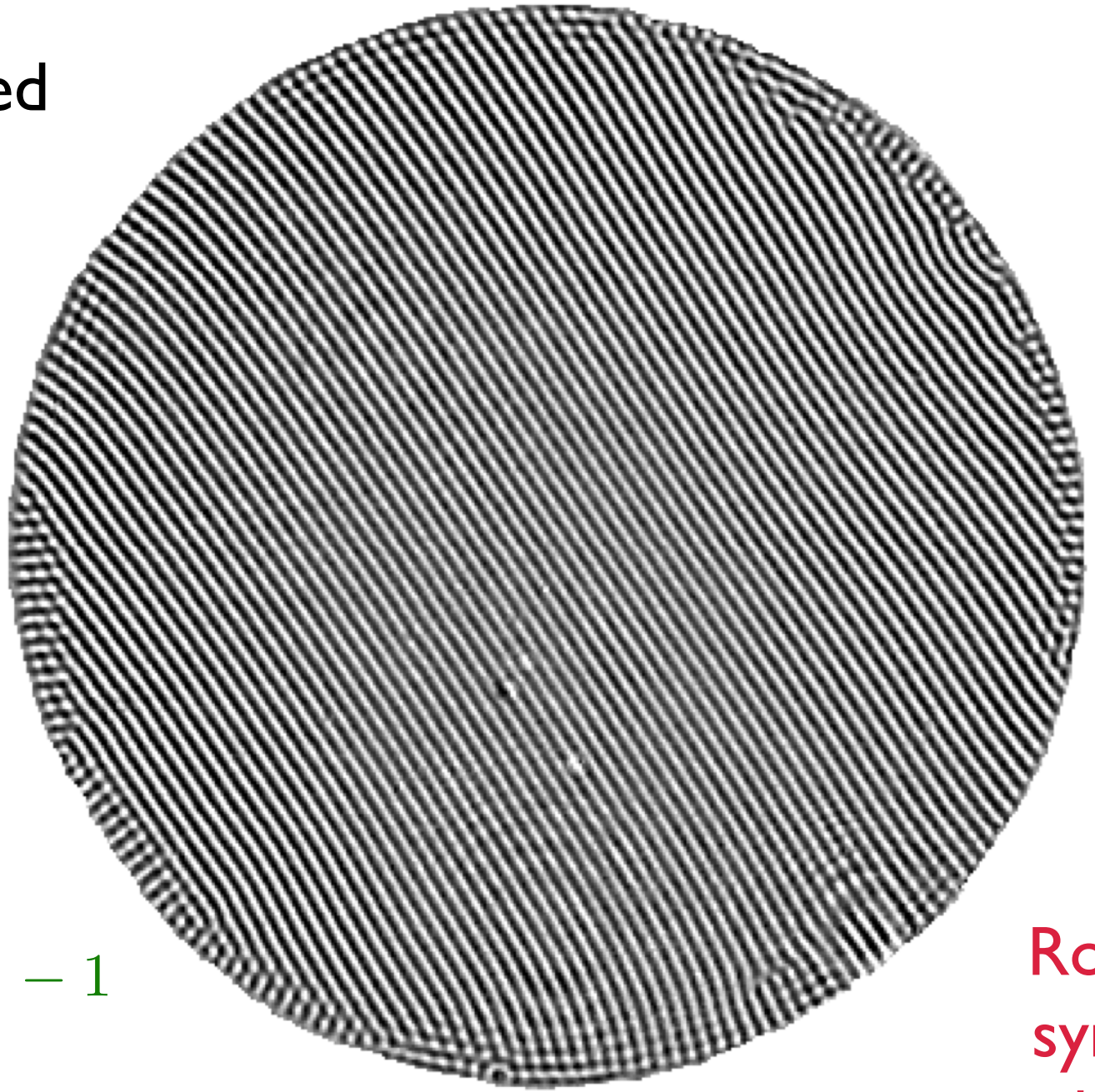
Simplest case, when ΔT is not too large, find *rolls*

"Boussinesq approximation", fluid properties are constant through the layer.



Boussinesq convection

Pressurized CO_2



$$\epsilon = \left[\frac{R}{R_c}\right] - 1$$

$\epsilon = 0.043$

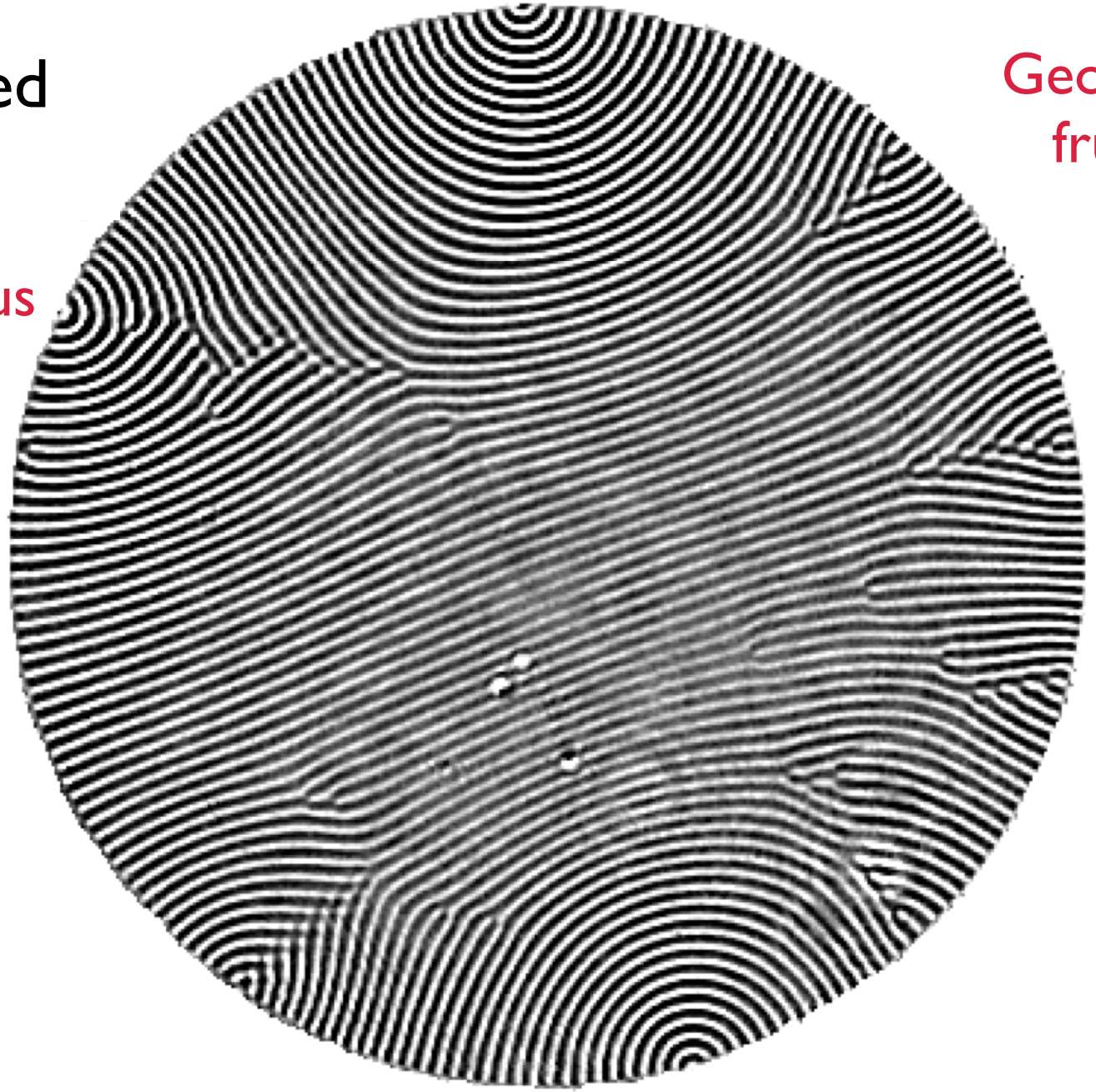
Rotational symmetry broken

Boussinesq convection

Pressurized CO_2

Geometrically frustrated

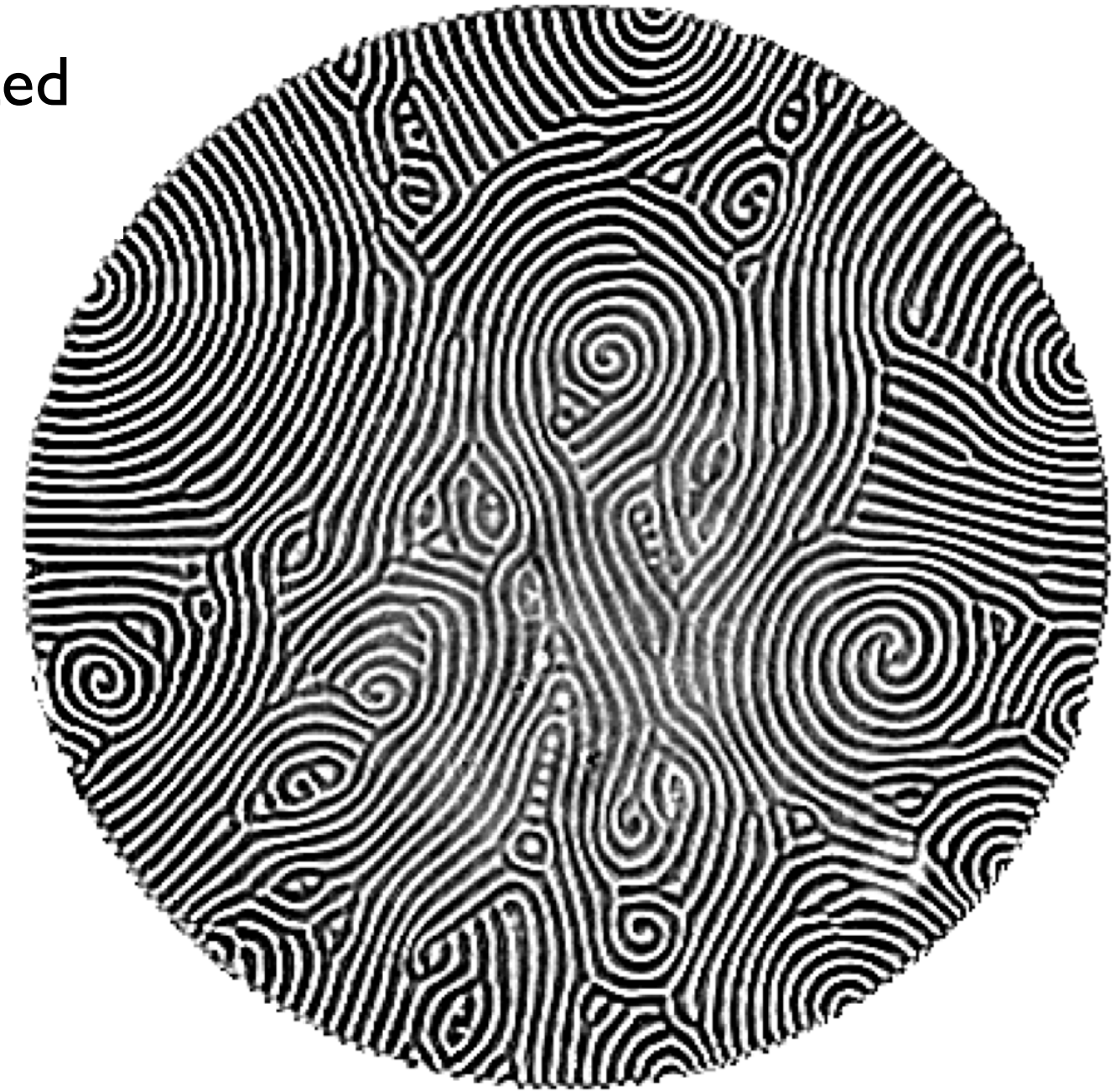
Focus



$\epsilon = 0.245$

Boussinesq convection

Pressurized CO_2

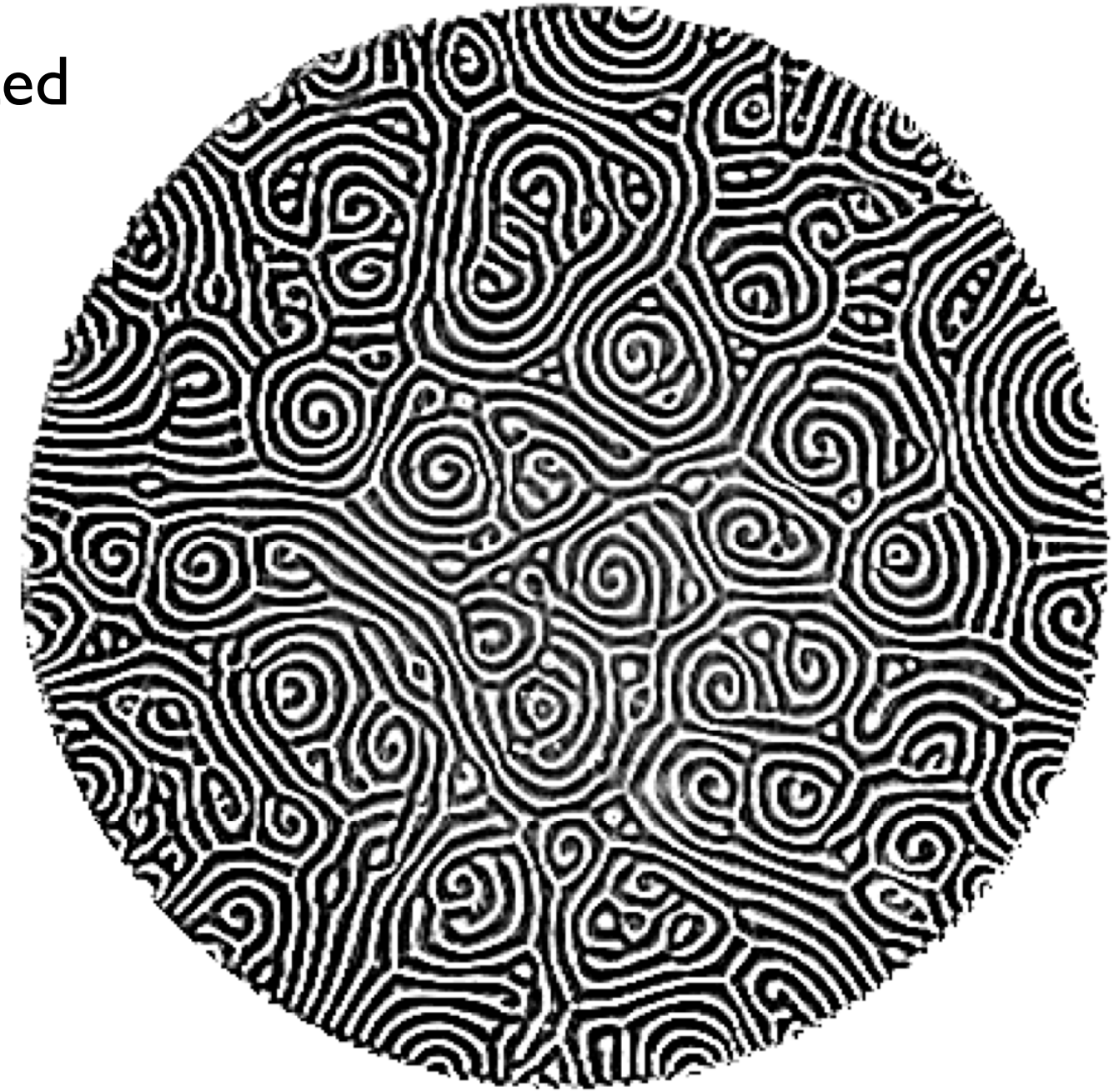


Spiral defects appear

$\epsilon = 0.536$

Boussinesq convection

Pressurized CO_2



Spiral defect chaos

$\epsilon = 0.894$

Boussinesq convection

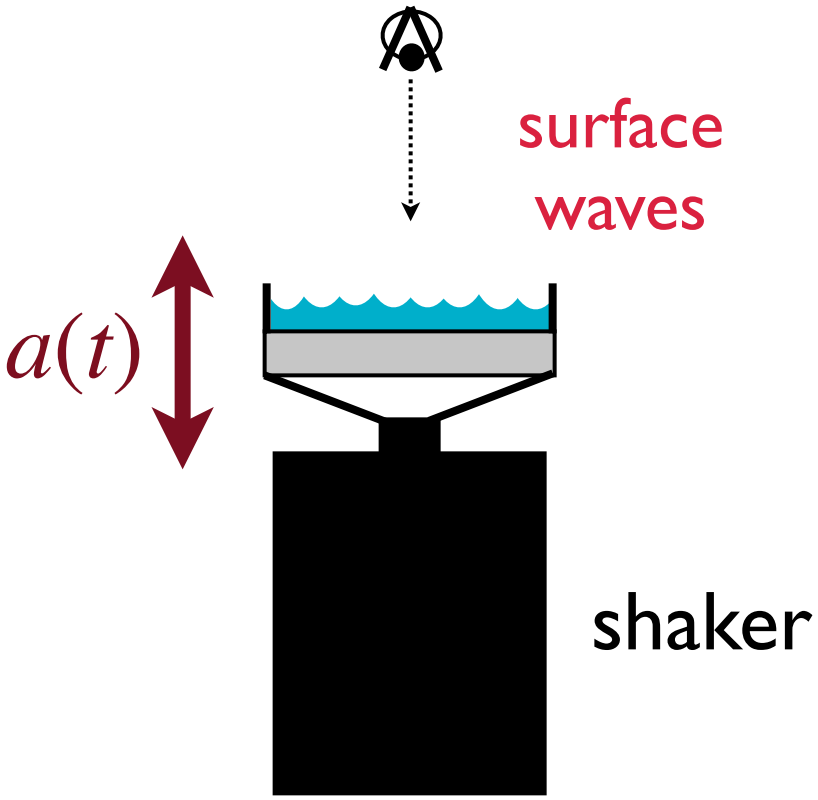
Pressurized CO_2

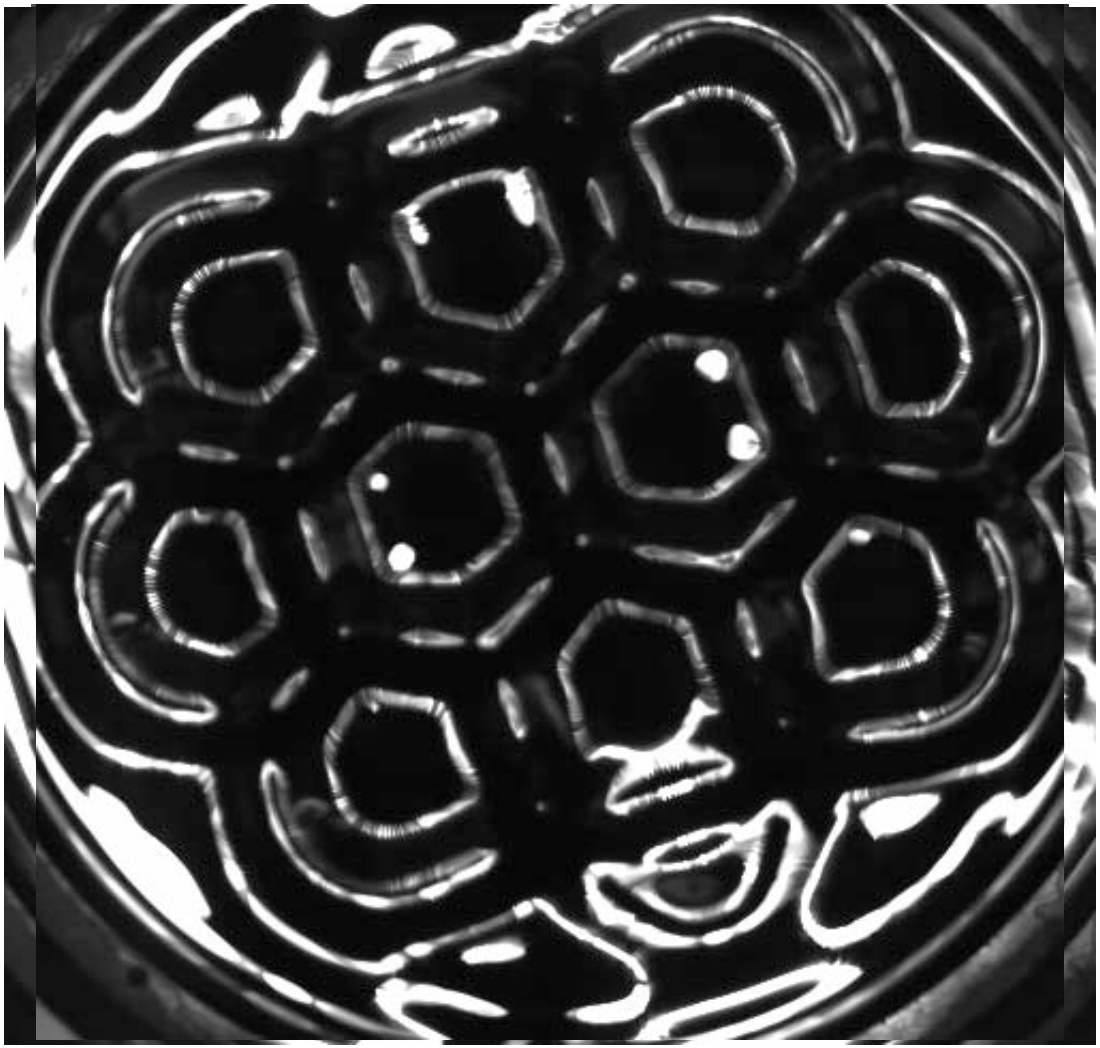
Spiral defect chaos

An example of "spatio-temporal chaos"

Another Classic: The Faraday Instability

Fluid layers subjected to vertical shaking

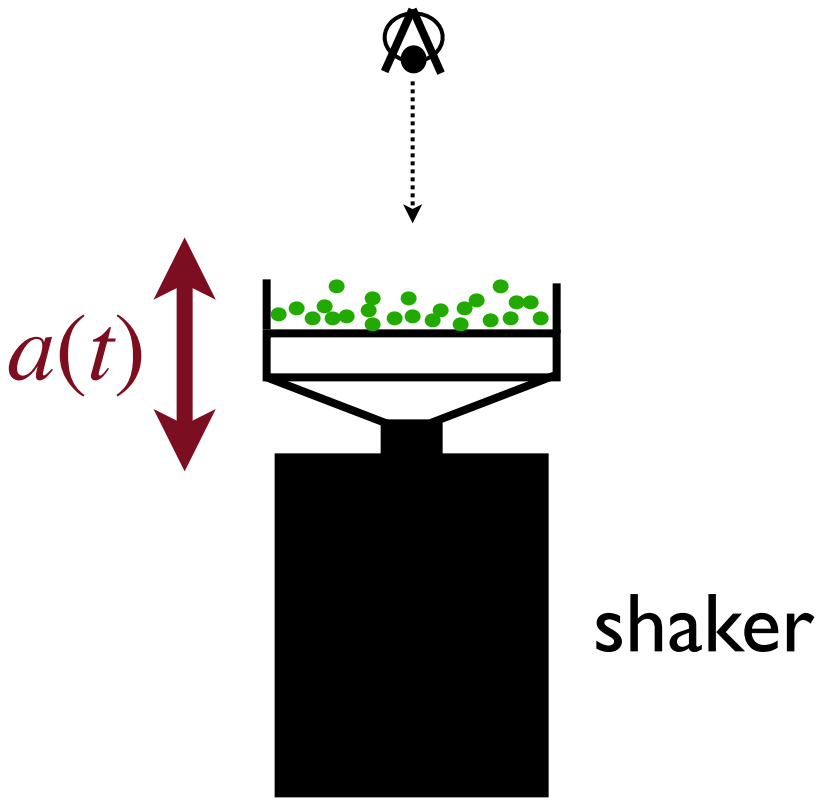




hexagons

Granular layers subjected to vertical shaking

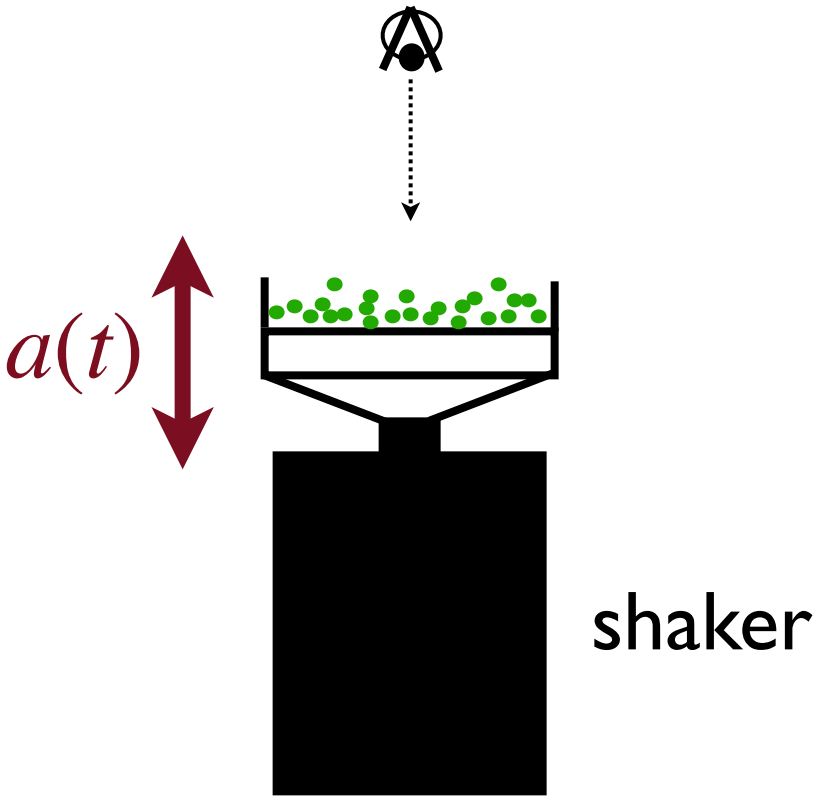
Vary depth, acceleration and frequency of shake



For $a(t) < 2.7\ g$, the granular layer bounces on the plate but remains uniform in thickness.

For $a(t) > 2.7\ g$ ....

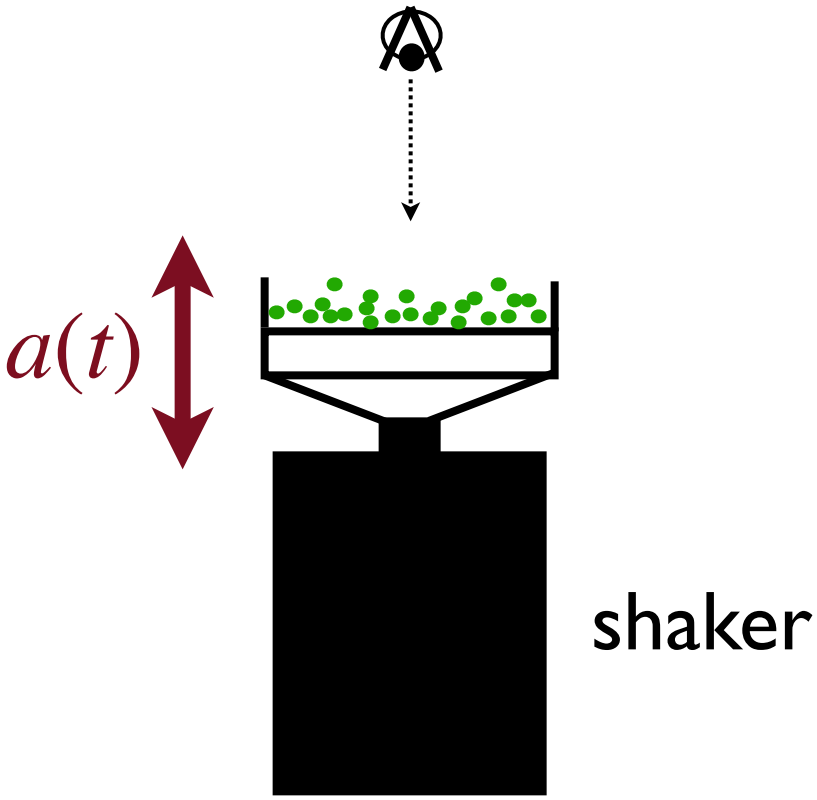
Granular layers subjected to vertical shaking



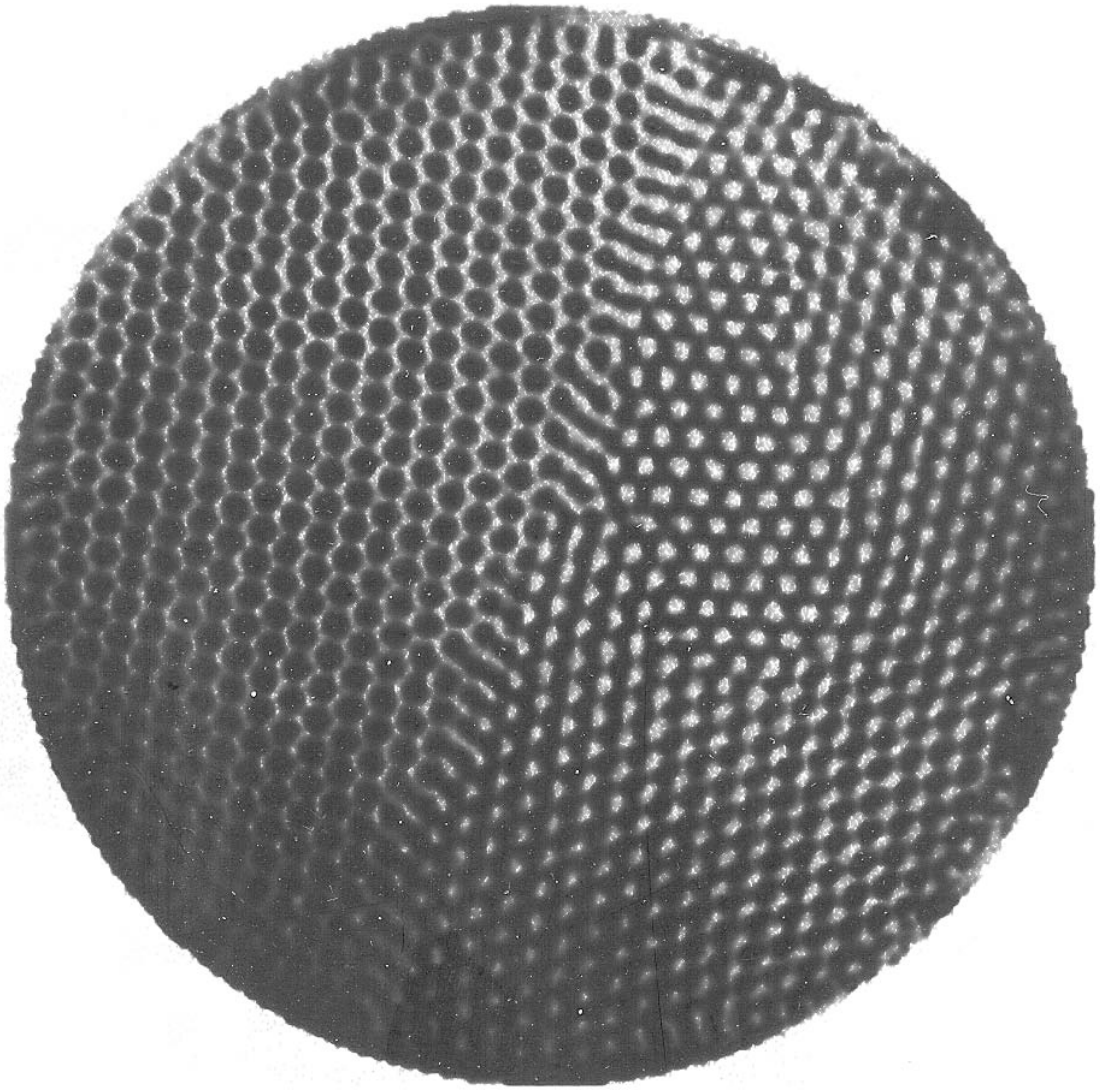
Square pattern

Texas group

Granular layers subjected to vertical shaking

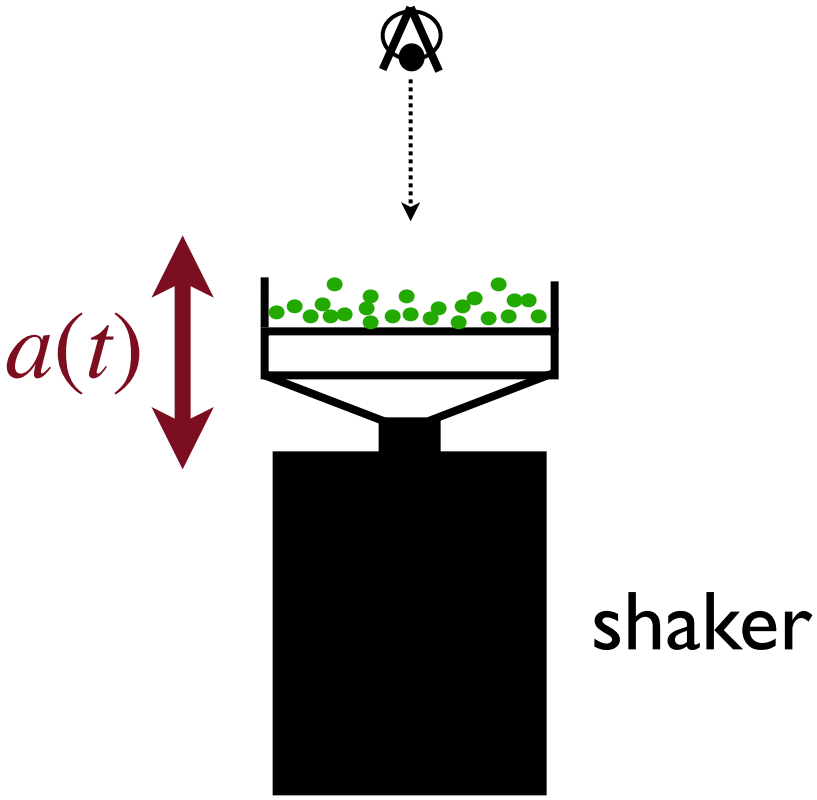


Hexagonal pattern

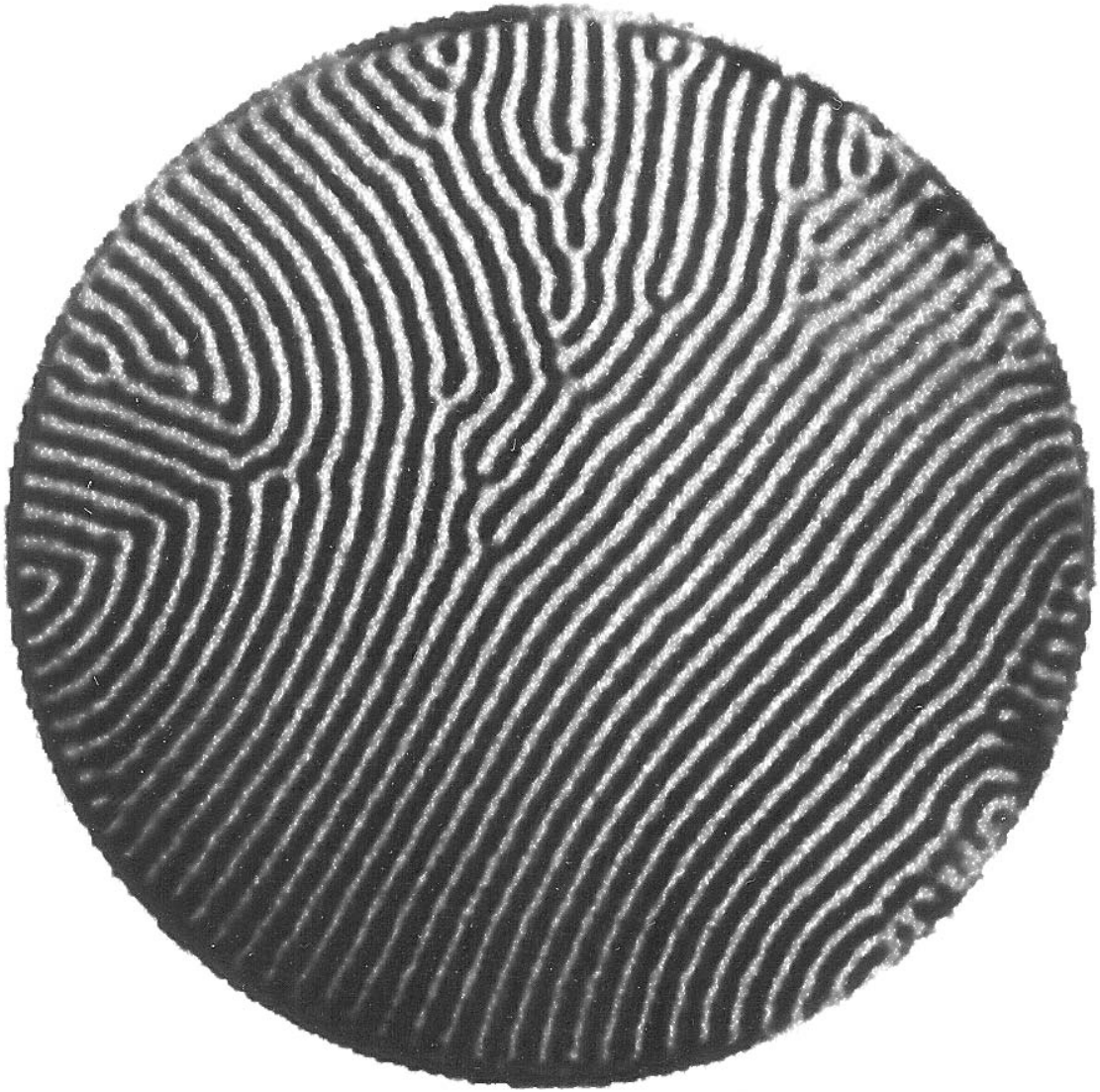


Texas group

Granular layers subjected to vertical shaking

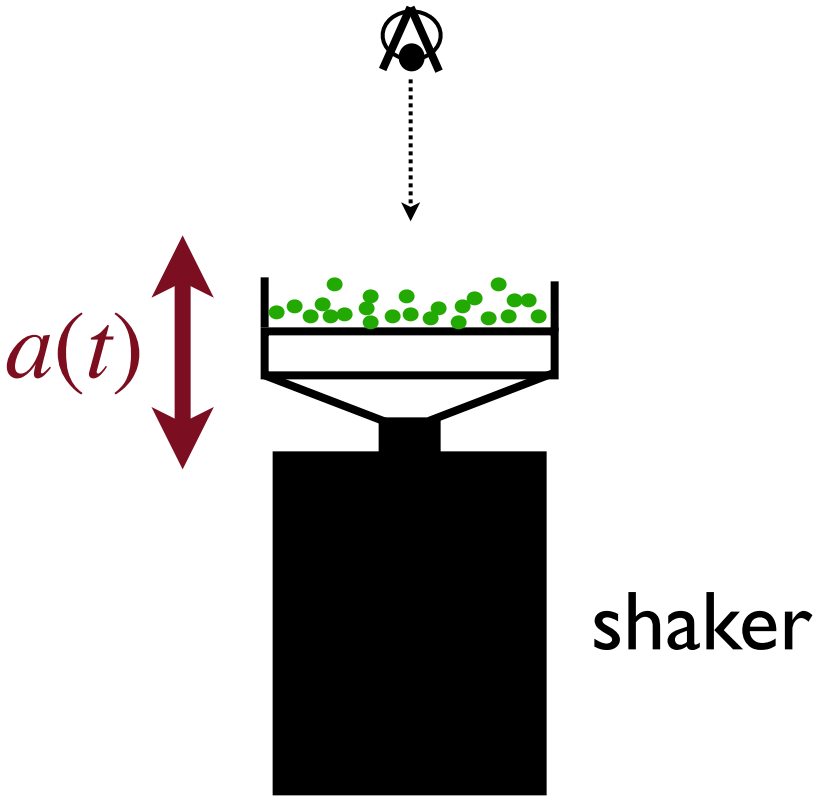


Stripe pattern

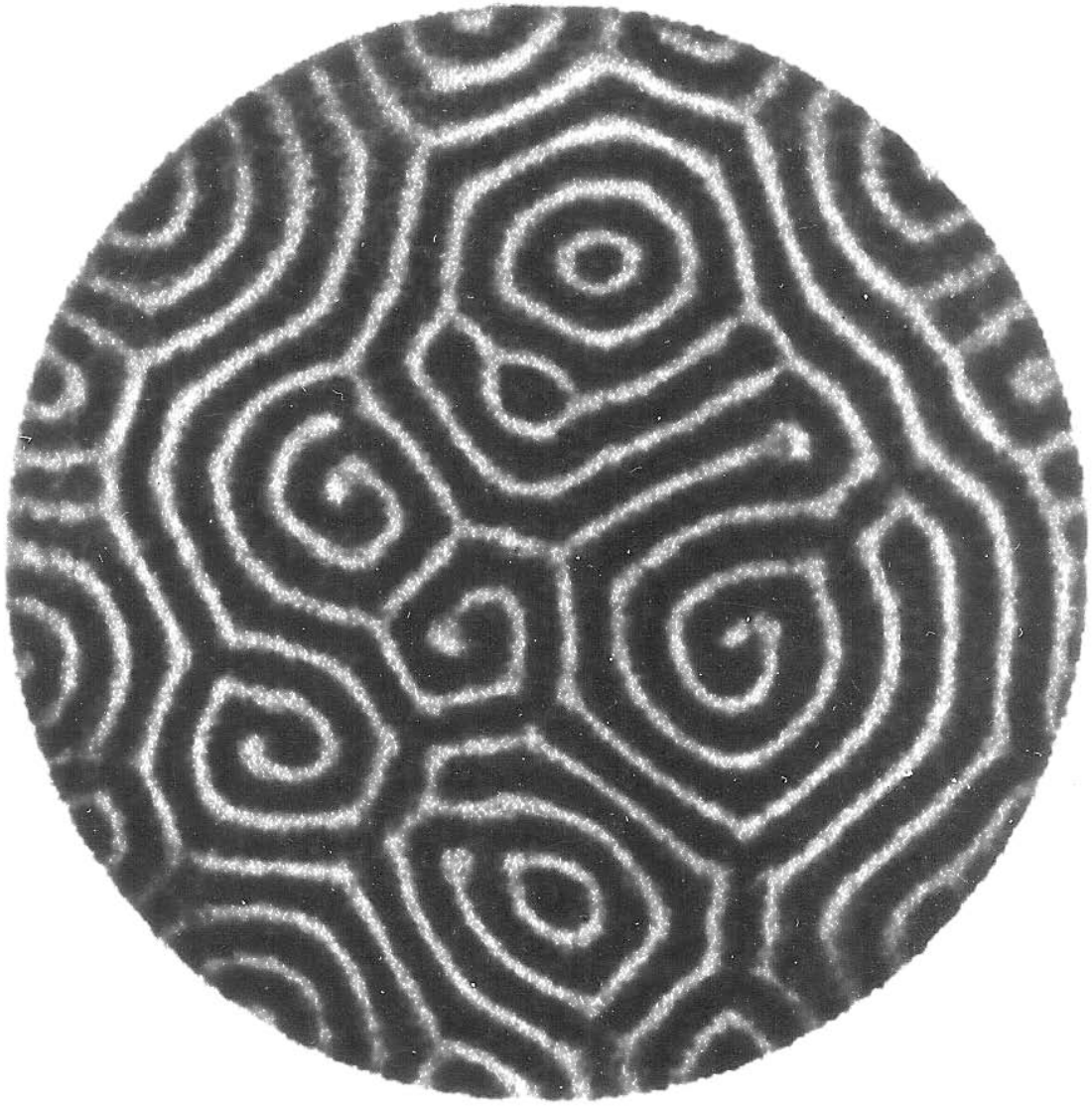


Texas group

Granular layers subjected to vertical shaking



"Spiral Defect Chaos"



Texas group

The pattern formation paradigm:

- Open, dynamic evolution, not balance in Nature.
- Stability and instability, not optimality.
- Expect emergence, not preformed design.
- Patterns, self-organization and complexity are a natural consequence of physical laws.