Imaging granular matter: some observations and challenges

Sept-Oct. 2004

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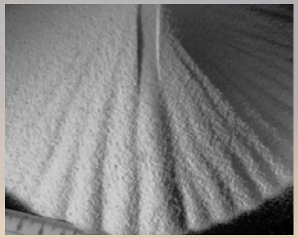
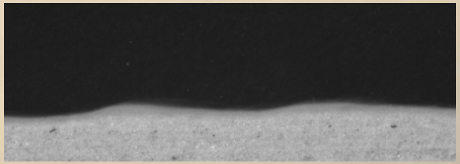
Revolving rivers

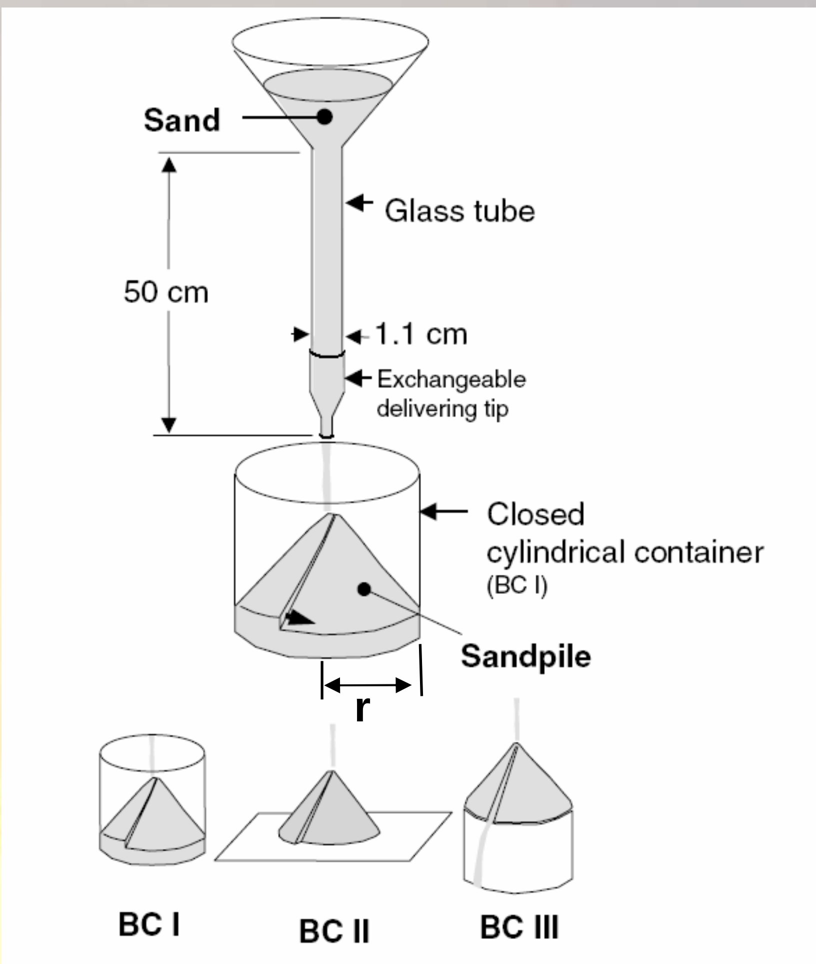


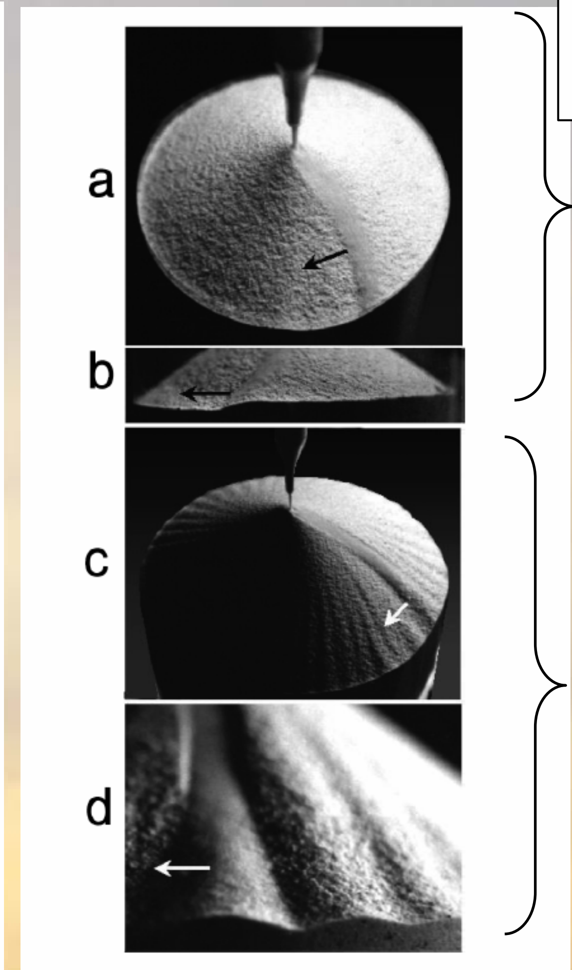
Uphill bumps

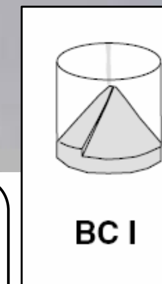


Other

Revolving rivers: introduction







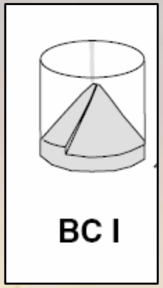
Continous rivers

(small radius)

Intermittent rivers

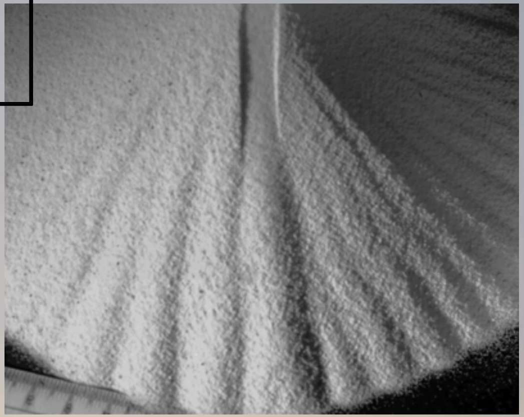
(bigger radius)

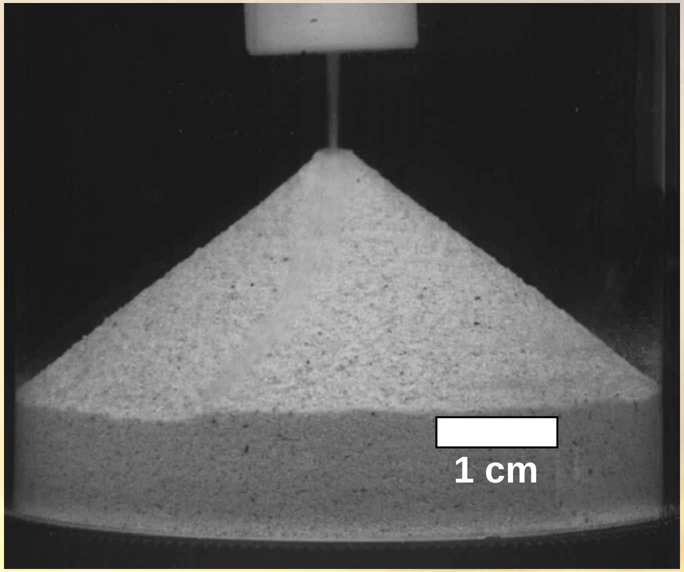
Revolving rivers: introduction

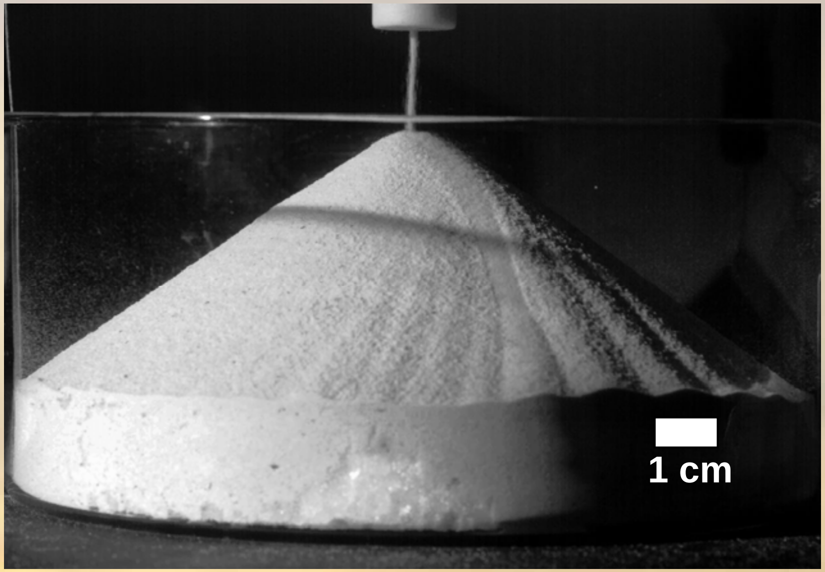


Continuous regime

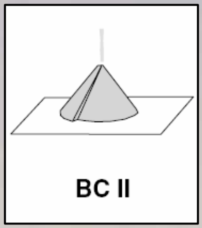
Intermittent regime

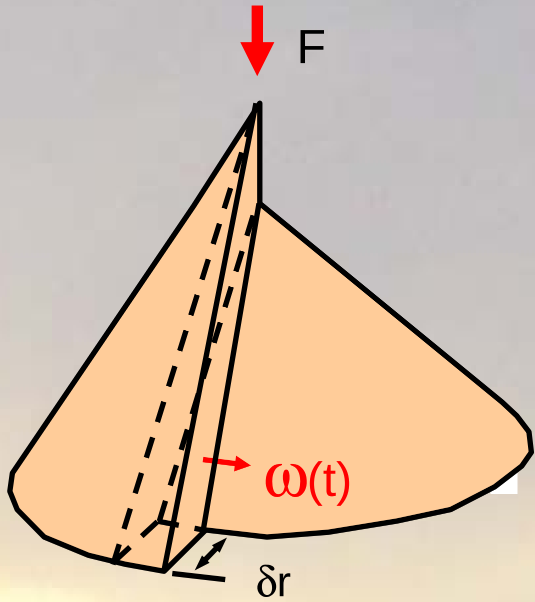






Revolving rivers: a simple, old model





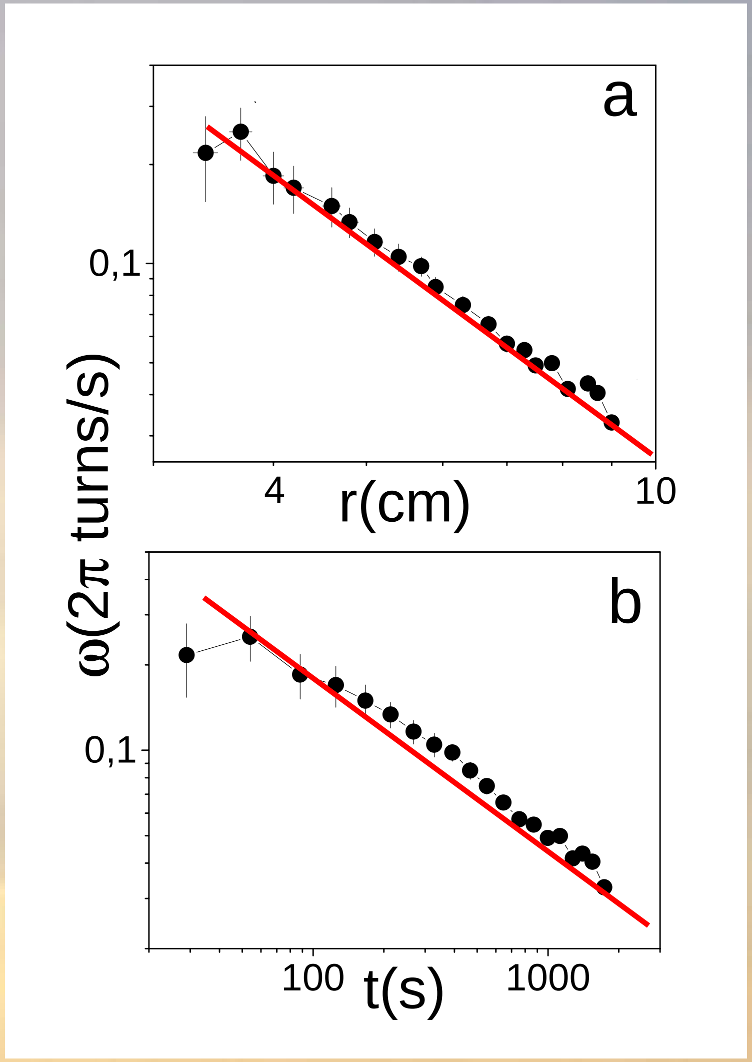
$$\omega = \frac{2F}{\tan\theta}\frac{1}{\delta r}\frac{1}{r^2}$$

$$\omega = \frac{2}{(\tan\theta)^{1/3}}\left(\frac{\pi}{3}\right)^{2/3} F^{1/3}\frac{1}{\delta r}\frac{1}{t^{2/3}}$$

$$F = 0,4 cm^3 / s$$

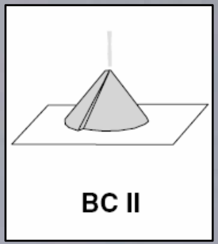
$$\theta = 33^o$$

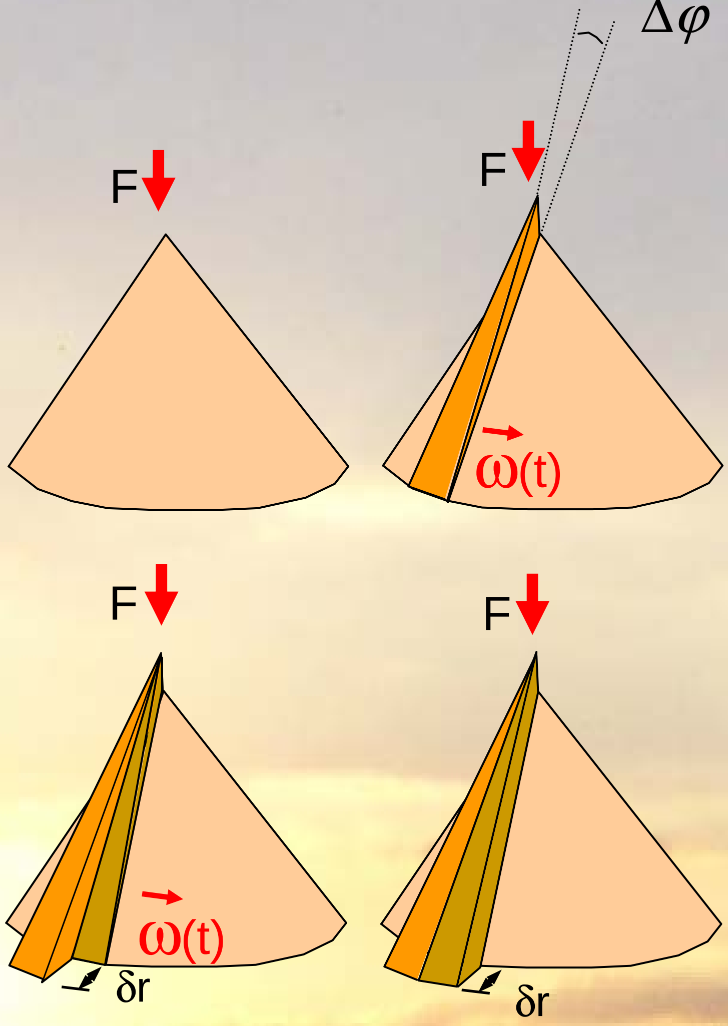
$$\delta r = 0,4 cm$$



Revolving rivers: the tickling model

(Herrmann & Toussaint)





$$\omega = 76 \frac{F\cos^2\theta}{\tan\left(\frac{3}{2}\Delta\varphi\right)} \frac{1}{r^3}$$

Assumption No. 1

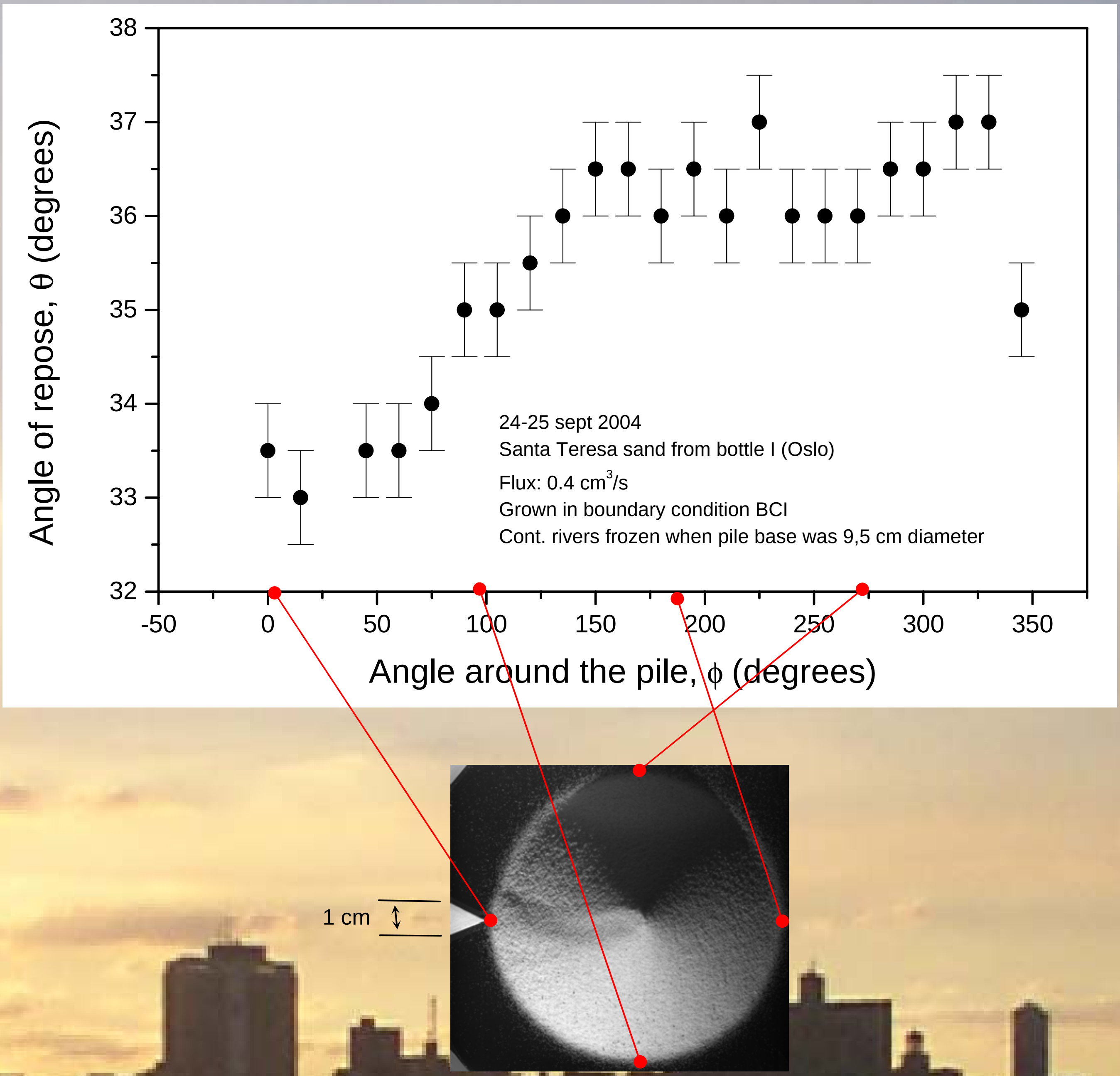
$$\Delta\varphi = const. \Rightarrow \omega \sim \frac{1}{r^3} \; (wrong!)$$

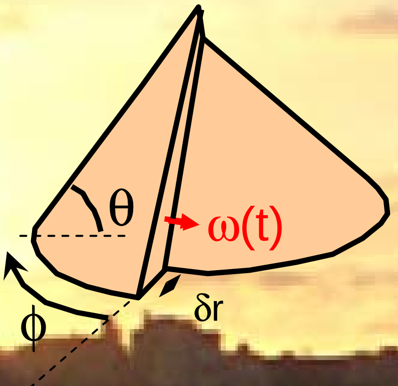
Assumption No. 2

$$\delta r = const. \Rightarrow \Delta\varphi \sim \frac{1}{r};$$

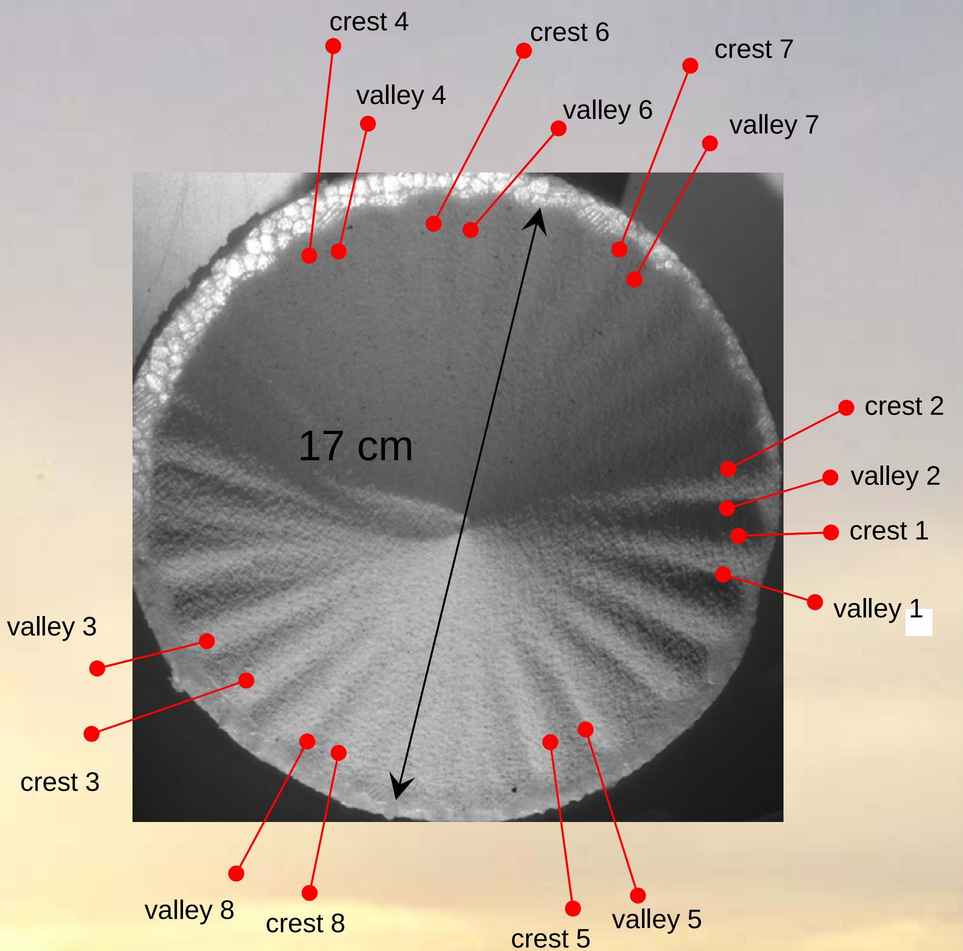
$$\omega = \frac{2F}{\tan\theta} \frac{1}{\delta r} \frac{1}{r^2} \; (old, correct \; formula)$$

Continuous rivers: angular realities

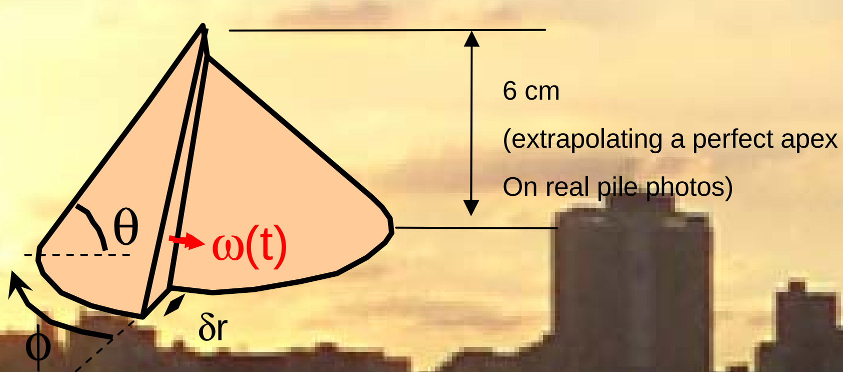




Intermittent rivers: angular realities

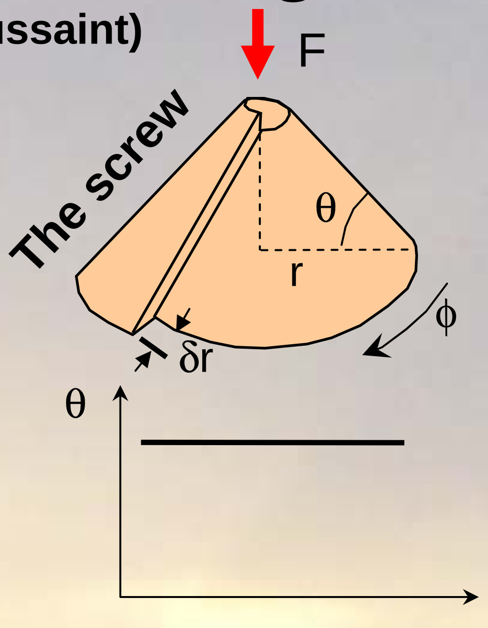


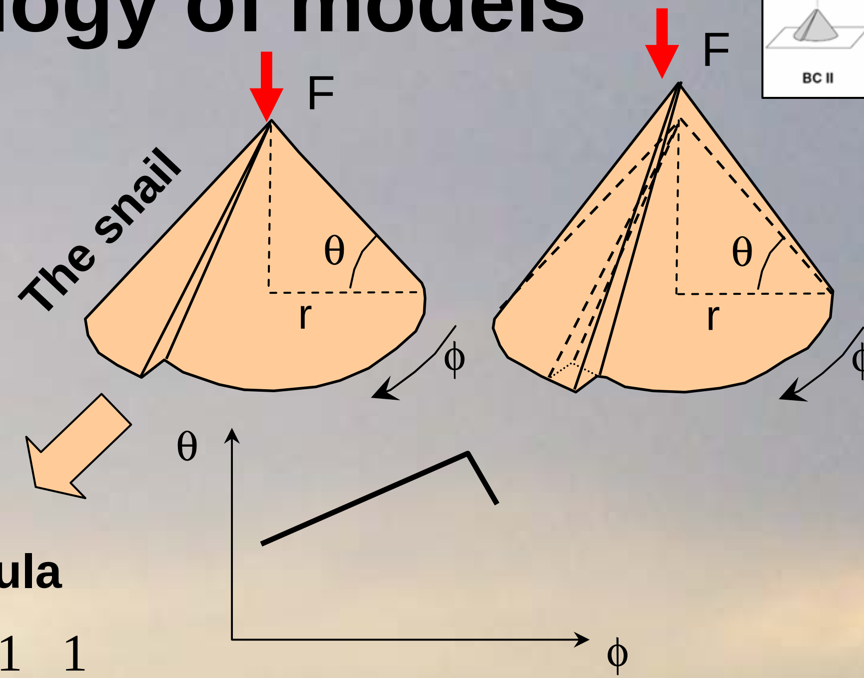
#	θ_{valley}	$\langle\theta_{valley}\rangle$	θ_{crest}	$\langle\theta_{crest}\rangle$
1	37		35	
2	37		36	
3	38		36	
4	37	37,1 ±0,16	36	36,1 ±0,20
5	37,5		36	
6	37		36,5	
7	37		36	
8	36,5		37	



Revolving rivers: a zoology of models

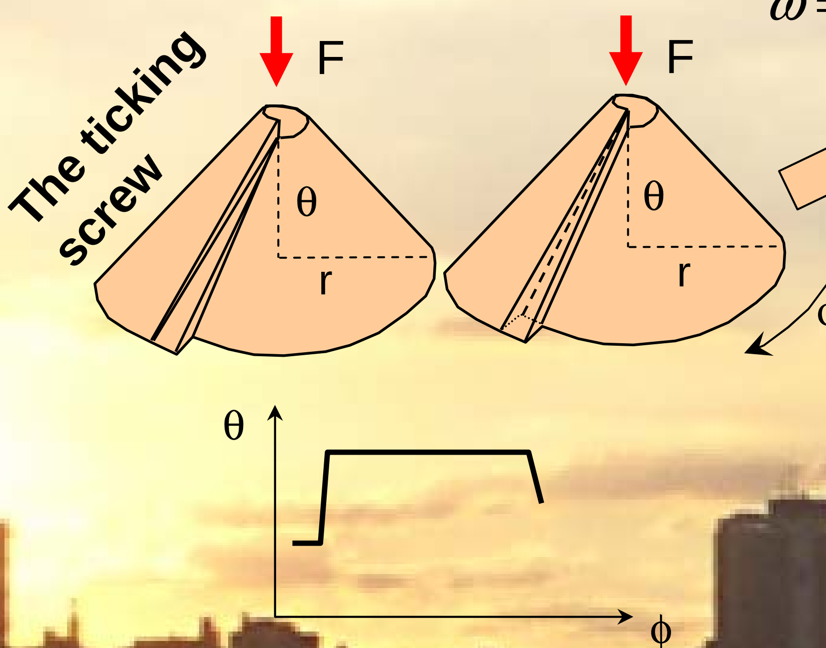
(Toussaint)

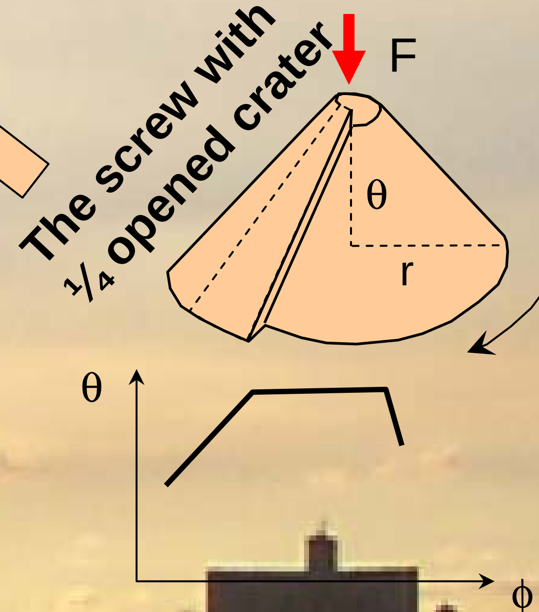




Old formula

$$\omega = \frac{2F}{\tan\theta}\frac{1}{\delta r}\frac{1}{r^2}$$

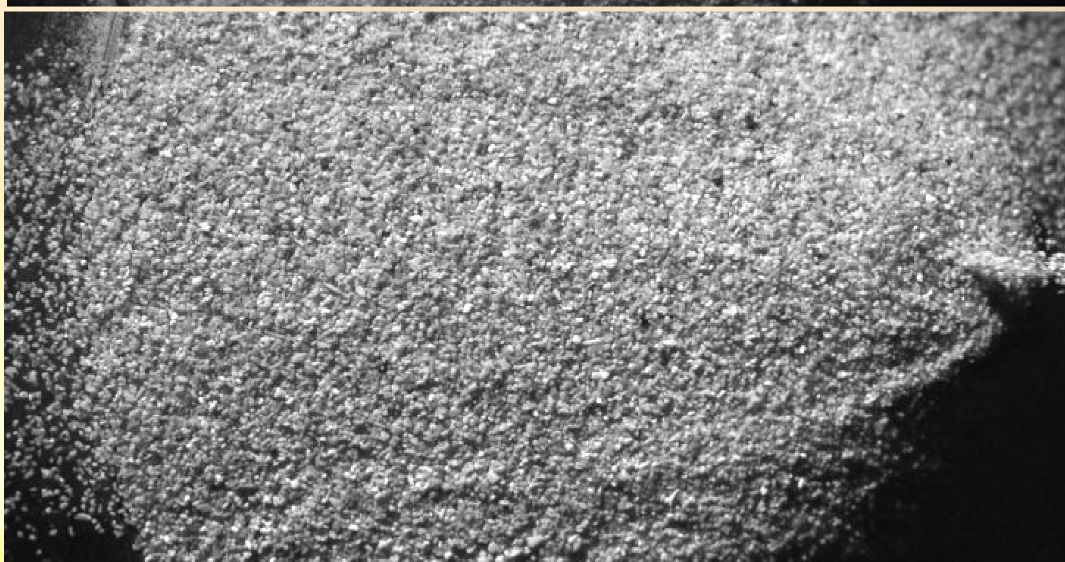




Why rivers, in the first place?

-- Spontaneous vs. Non-spontaneous symmetry breaking

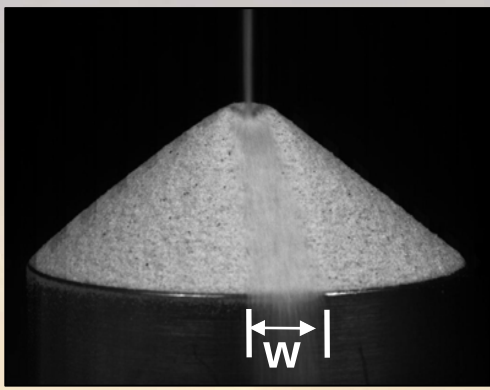
Revolving sand (Santa Teresa)

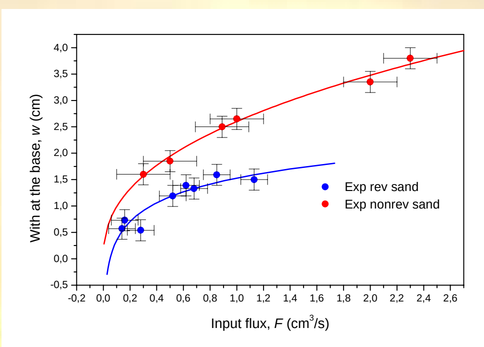


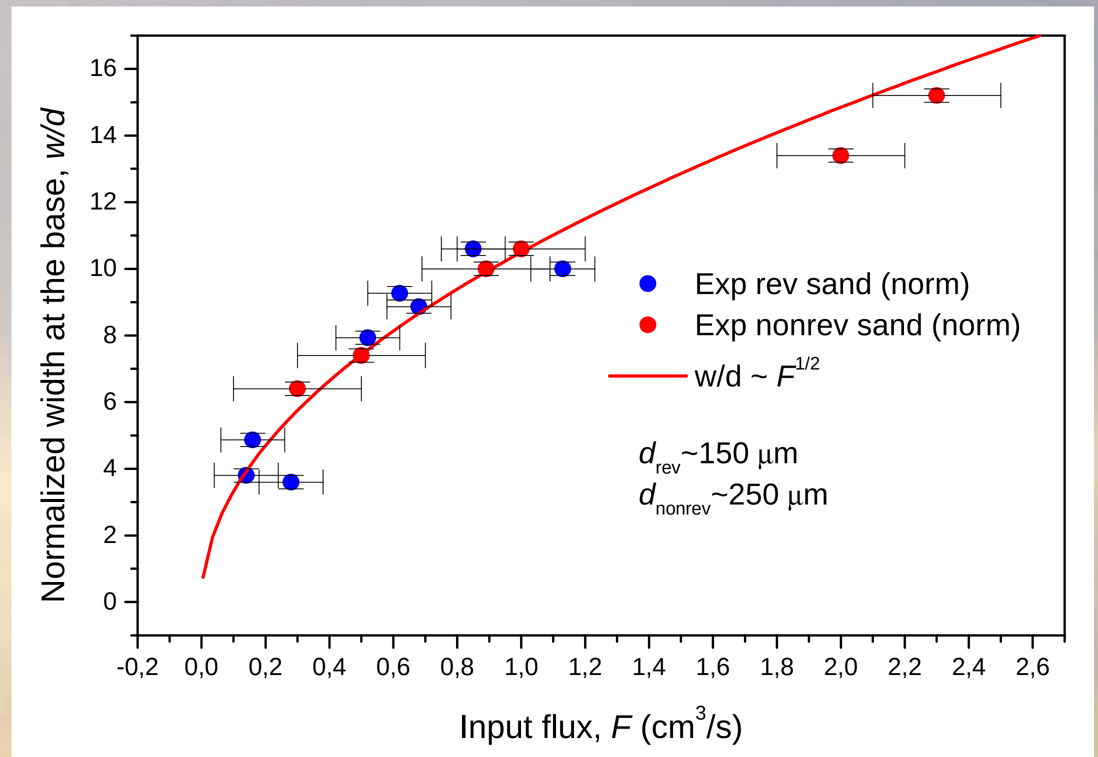
Non-revolving sand (Varadero)

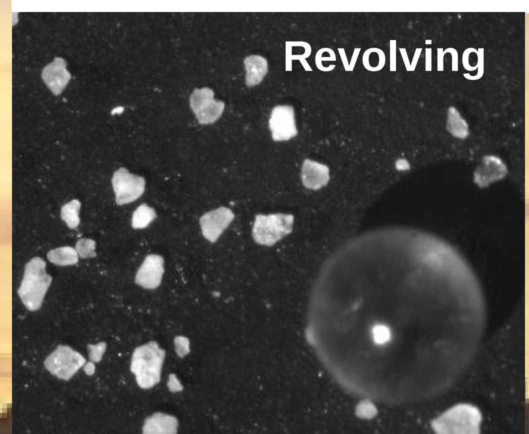
Why rivers, in the first place?

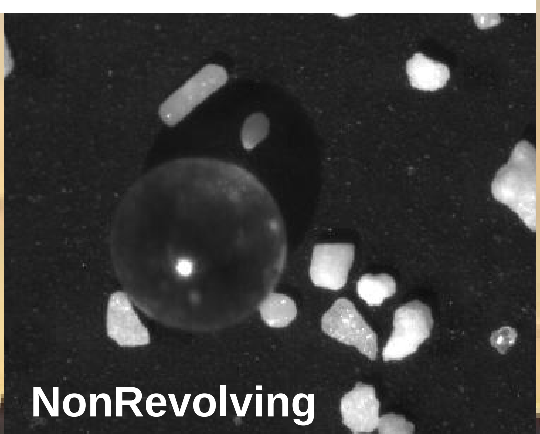
-- The geometry of the flow: a possible hint









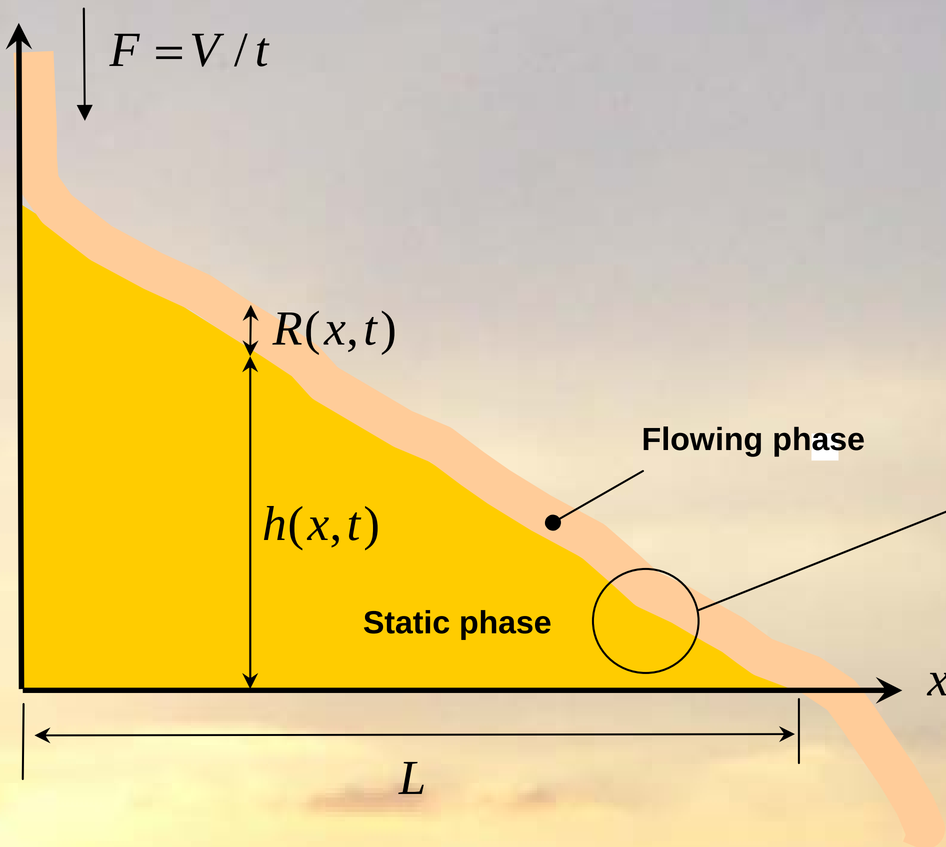


Flowing sand: the BCRE model

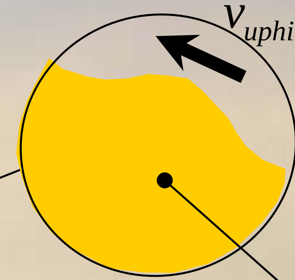
Bouchaud, Cates, Prakash & Edwards, J. Phys. France 4 (1994) 1383

$$\frac{\partial R}{\partial t} \approx -\frac{\partial h}{\partial t} + v\frac{\partial R}{\partial x}$$

$$\frac{\partial h}{\partial t} \approx \gamma R(\theta_n - \theta)$$



$$v_{uphill} = \gamma R = \sqrt{\frac{g}{d}}\, R$$



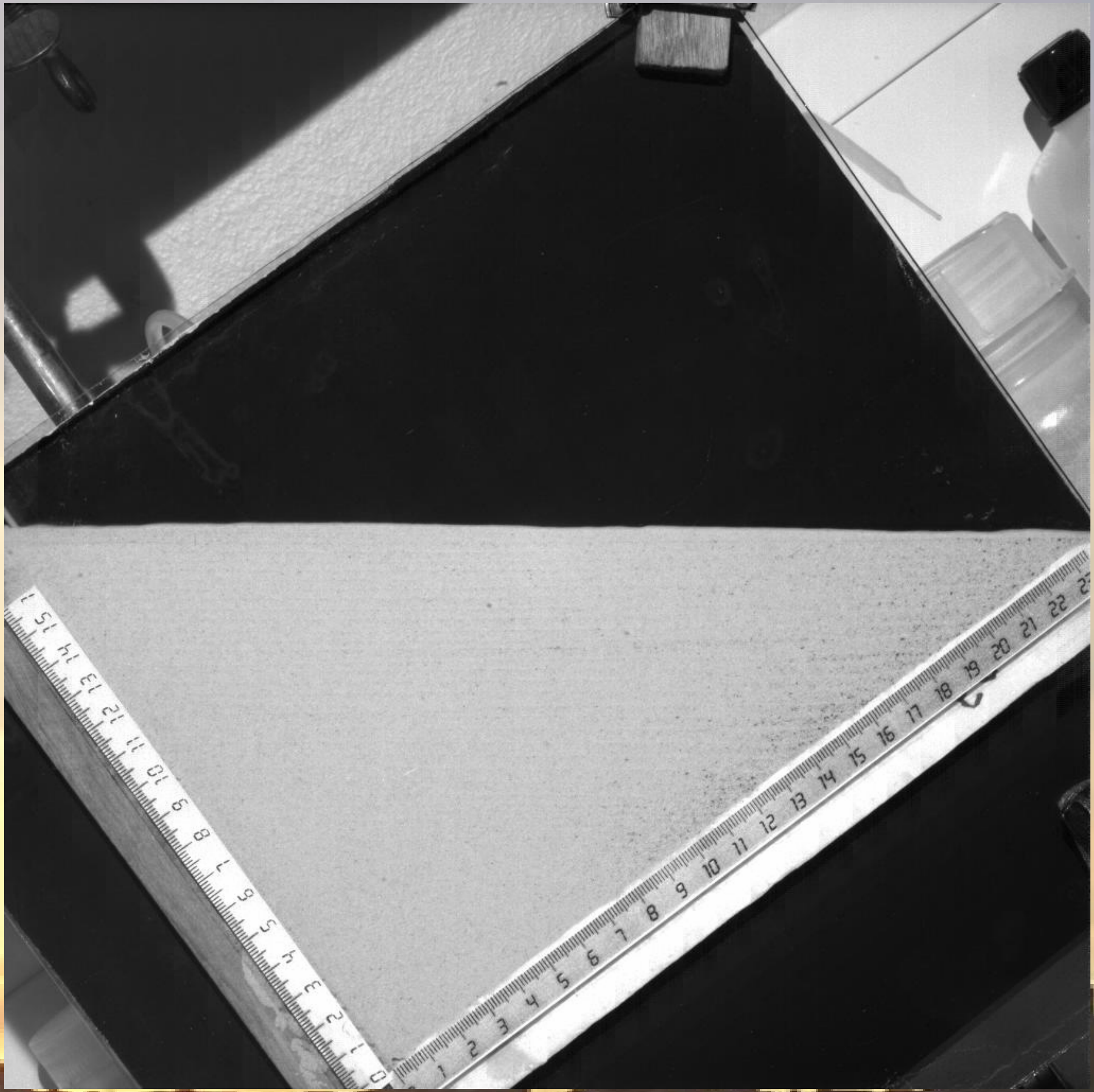
For spheroidal grains and ”average levels of inelastic collisions”

Accident in slope (”bump”)

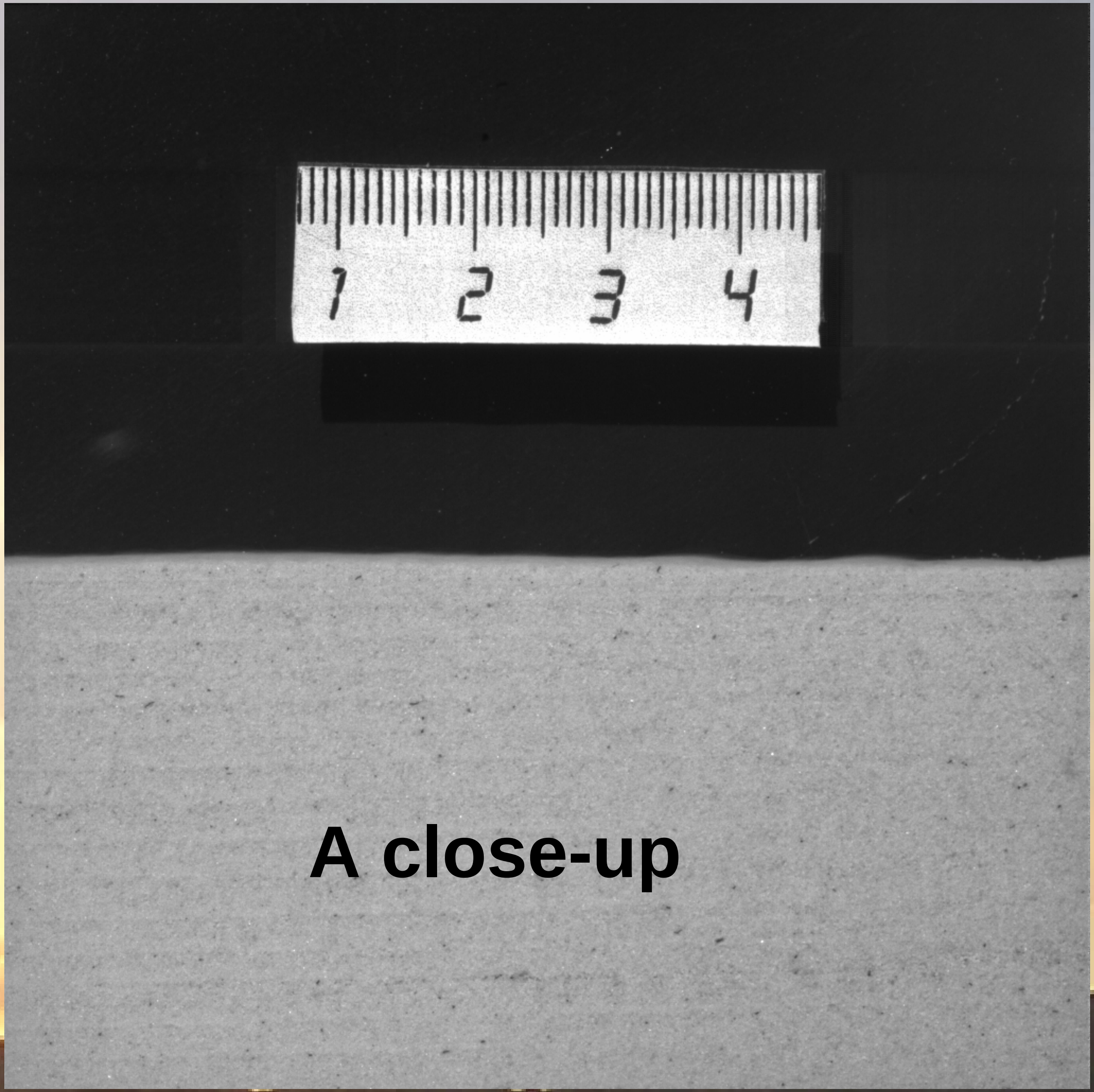
Following the simplification by Boutreux, Raphael and DeGennes, Phys. Rev. E 58 (1998) 4892

$$\frac{\partial h}{\partial t} \approx v_{uphill}(\theta_n - \theta), \quad v_{uphill} \sim \frac{Q}{L(\theta_n - \theta)}$$

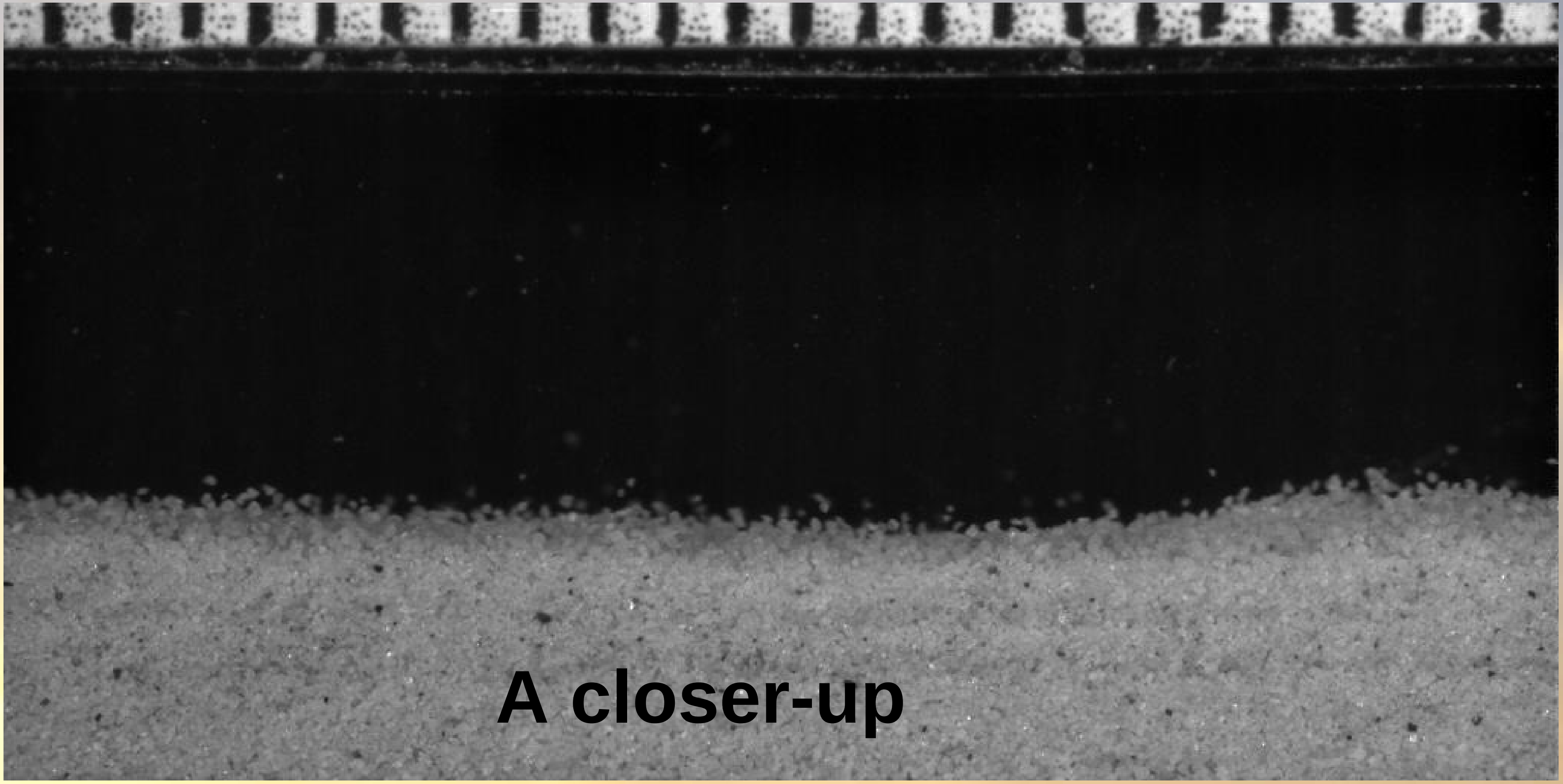
Experimental observation of ”uphill” bumps



Experimental observation of ”uphill” bumps



Experimental observation of ”uphill” bumps



Checking some BCRE predictions

In our case,

$$L = 240mm$$

$$\theta_n - \theta \approx 3^o$$

$$d \approx 100\mu m$$

$$R \approx 1,5mm$$

So the BCRE theory gives

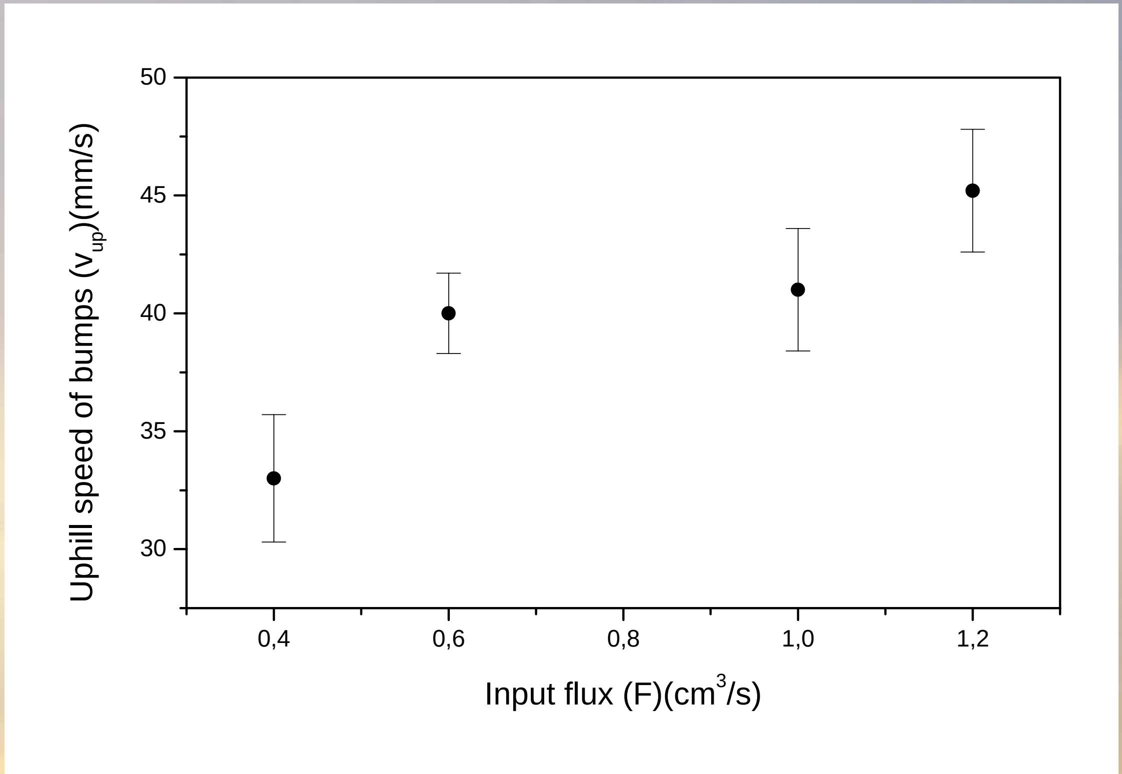
$$v_{uphill} = \sqrt{\frac{g}{d}}R \approx 30cm/s \ldots too\ big!$$

$$\gamma \approx 32s^{-1}$$

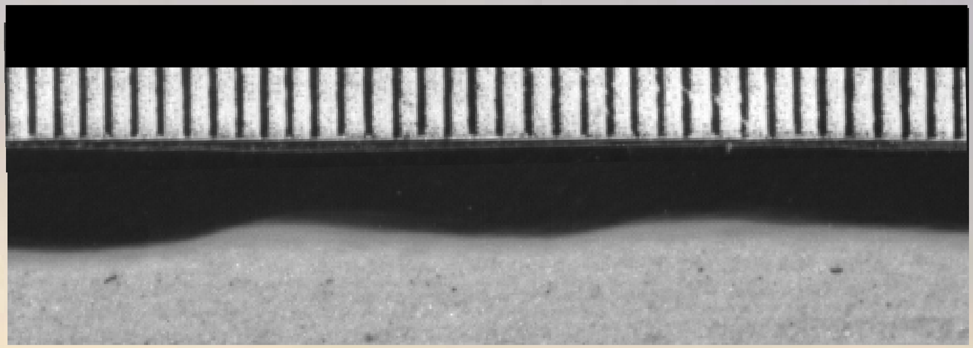
and the BRDG one gives

$$v_{uphill} \sim \frac{F_{2D}}{L(\theta_n - \theta)} \approx \frac{F_{3D}}{Lw(\theta_n - \theta)} \approx 2F_{3D}$$

Our measurements



Moving bumps in heaps and tubes: a misleading resemblance?

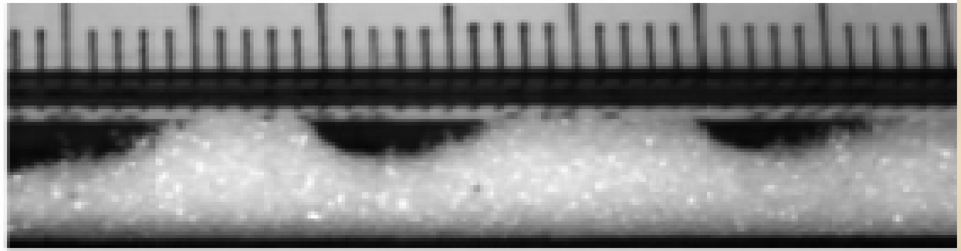


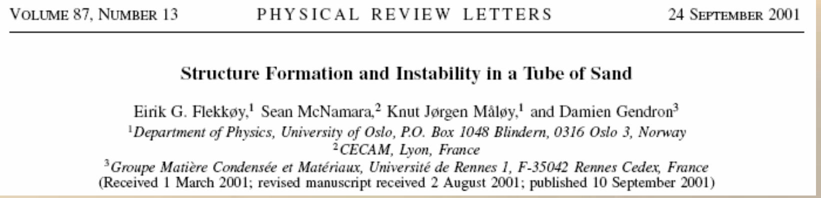
$$d \approx 100\mu m$$

$$R \approx 1,5mm$$

$$\theta \approx 33^o$$

$$v_{uphill} \sim 20-50mm/s$$





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Structure Formation and Instability in a Tube of Sand

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$$d \approx 180\mu m$$

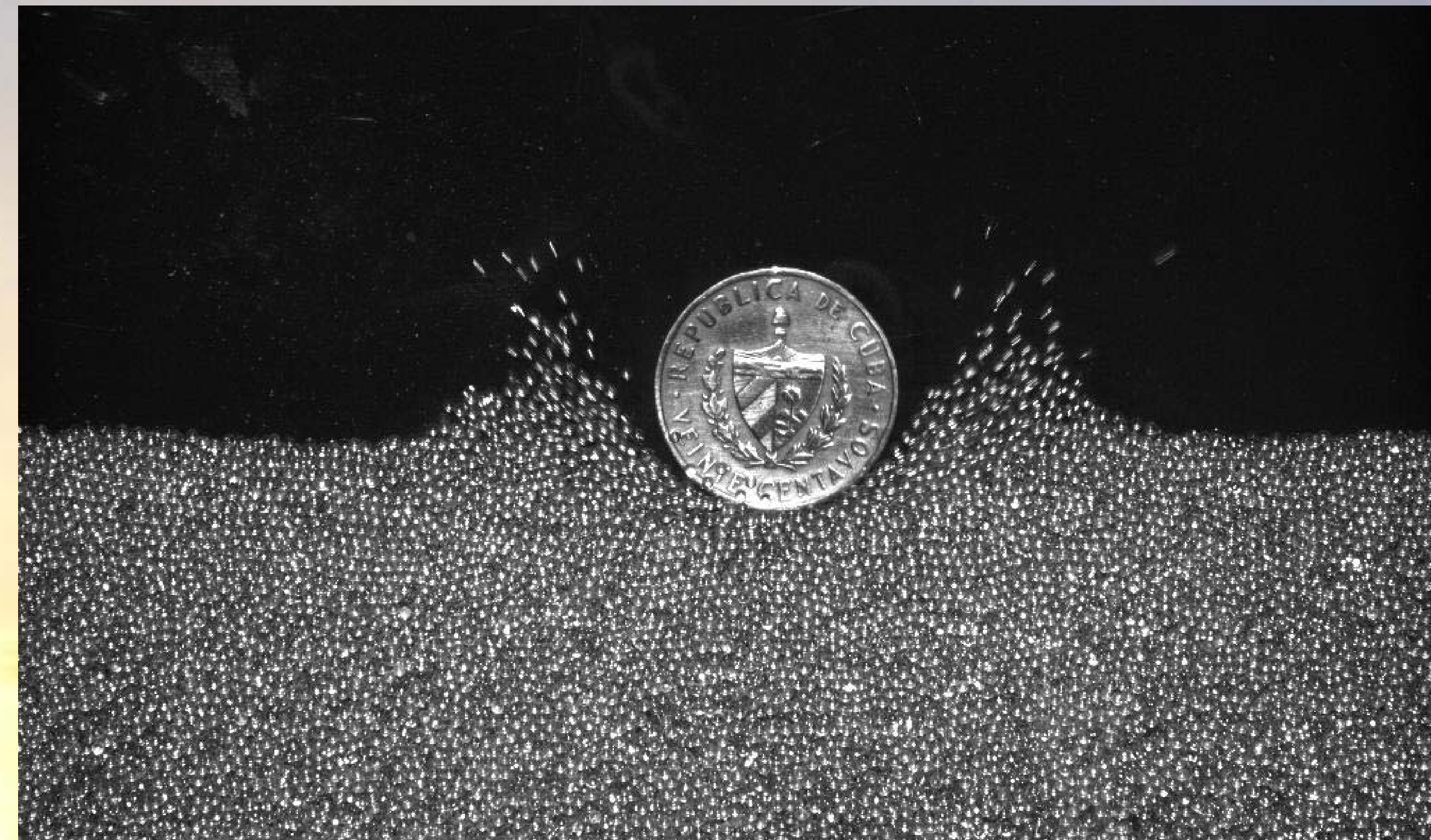
$$R \approx 1,5mm$$

$$\theta \approx 70^o$$

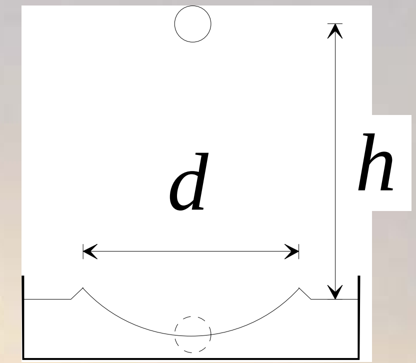
$$v_{uphill}^{bubbles} \sim 100-500mm/s$$

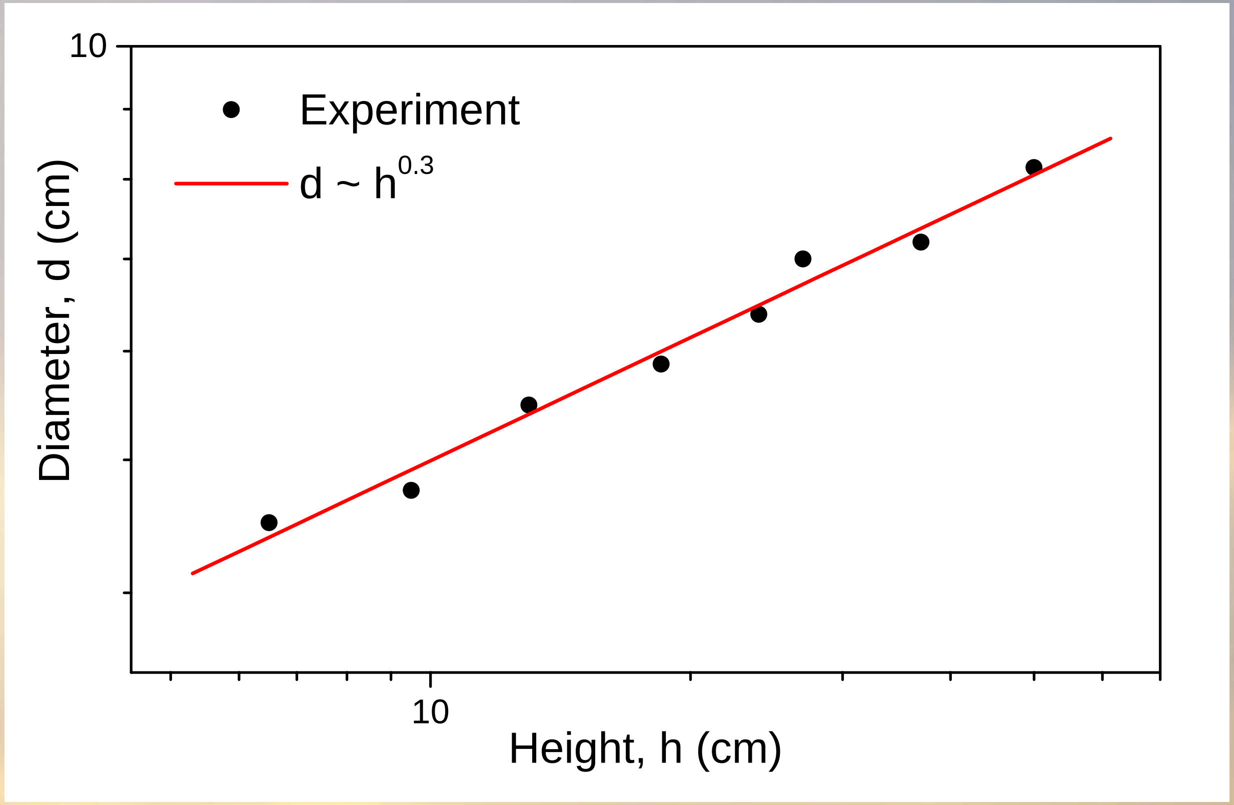
Other stuff:

Introducing a really inexpensive experiment



Impact cratering: a simple exercise





Impact-explosion analogy (3D)

$$d \propto E^{1/3}$$

Gravitational energy (3D)

$$d \propto E^{1/4}$$

Gravitational energy (Ideal 2D)

$$d \propto E^{1/3}$$