

Wetting of Surfaces Covered by Elastic Hairs

Nelson Rei Bernardino¹, Valentin Blickle² & Siegfried Dietrich³

¹Centro de Física Teórica e Computacional
Universidade de Lisboa, Portugal

²Physikalisches Institut
Universität Stuttgart, Germany

³Max-Planck-Institut für Metallforschung
Stuttgart, Germany

International Soft Matter Conference 2010
Granada, 7 July 2010

Wetting and Substrate Geometry

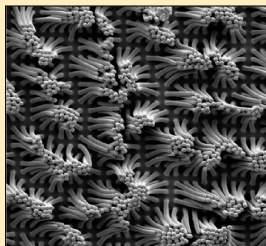
Geometry \rightarrow Wetting

- Capillary condensation.
- Wedge wetting.
- Superhydrophobic surfaces.¹



Geometry \leftarrow Wetting

- Deformation of elastic surfaces.
- Collapse of patterned substrates.²



Goal: Geometry \Leftrightarrow Wetting.

¹Lau *et al*, *Nanoletters* **3** (2003), 1701

²Chandra *et al*, *ACS Appl. Mater. Interfaces* **1** (2009), 1968

An Intriguing Example: The Lady's Mantle

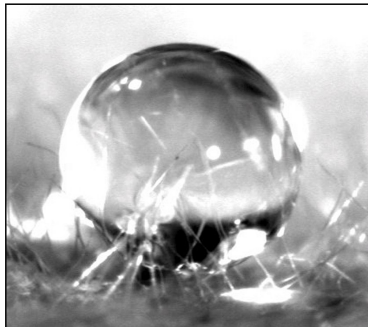


An Intriguing Example: The Lady's Mantle



An Intriguing Example: The Lady's Mantle

- Droplets can be suspended in the fur:



- Hairs are hydrophilic.¹
- Behavior attributed to elasticity of the hairs.

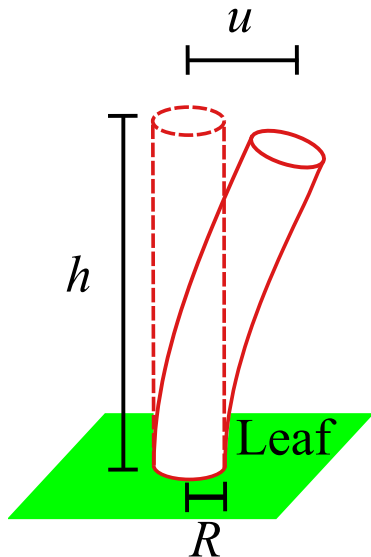
¹Otten & Herminghaus, *Langmuir* **20** (2004) 2405

Simple Model I: Elastic Energy

- Elastic Energy

$$E_{el} = \frac{3\pi ER^4}{8h^3} u^2$$

- $E \equiv$ Young's modulus.
- $R \equiv$ radius of posts.
- $h \equiv$ height.
- $u \equiv$ deviation from equilibrium position.

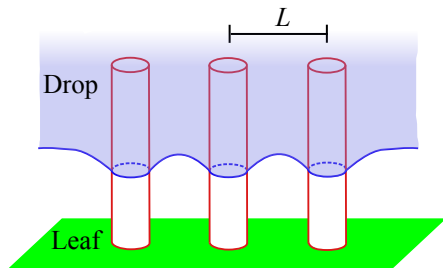


Simple Model II: Capillary Interaction

- Capillary Energy

$$E_{\text{cap}} = 2\pi\sigma R^2 \ln(qL) \cos^2 \theta$$

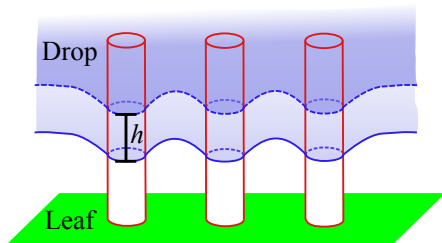
- $\sigma \equiv$ surface tension.
- $\theta \equiv$ contact angle.
- $q^{-1} \equiv$ capillary length.
- $L \equiv$ distance between centers of posts.



Simple Model III: Wetting Energy

- Wetting Energy

$$E_{\text{wet}} = 2\pi Rh\sigma \cos \theta$$



Some Remarks

- Thermal fluctuations are too small.
- Non-dimensionalising we have

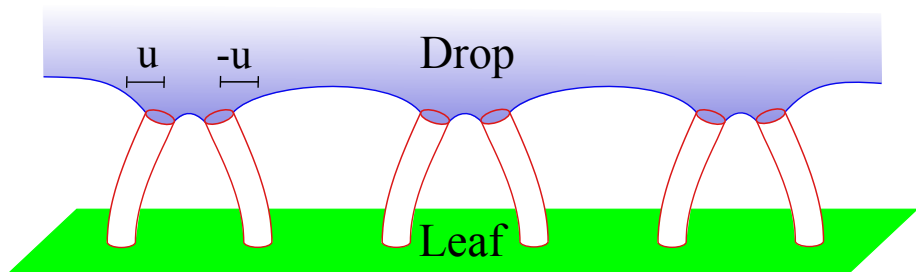
$$\bar{H} = \bar{h} \cos \theta + \frac{\bar{k}}{\bar{h}^3} \bar{u} + \ln(\bar{L}) \cos^2 \theta$$

- Essential parameter:

$$\bar{k} = \frac{3ER}{16\sigma}$$

- The Young's Modulus of the Lady's Mantle hairs is not known but a lower estimate is $\bar{k} \gtrsim 50$.

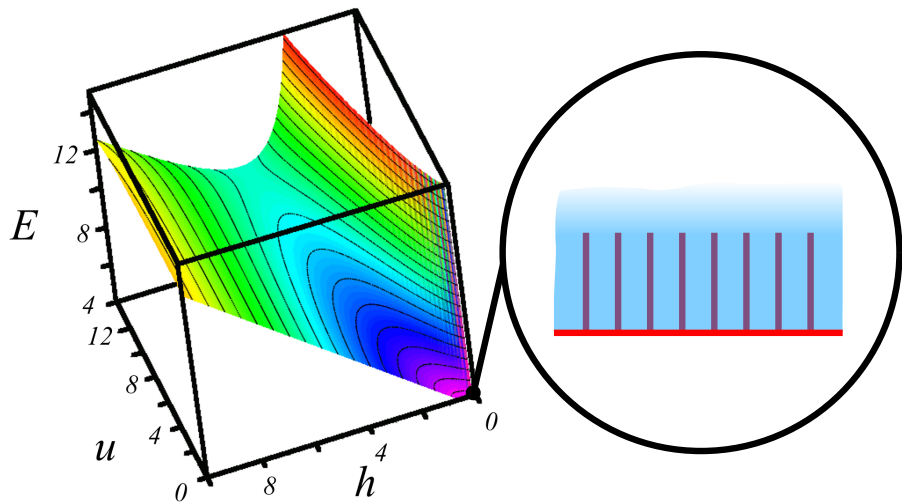
1D Toy Model I



$$H(u, h) = h \cos \theta + \frac{k}{h^3} u^2 + \frac{\ln(L - 2u) \cos^2 \theta}{2} + \frac{\ln(L + 2u) \cos^2 \theta}{2}$$

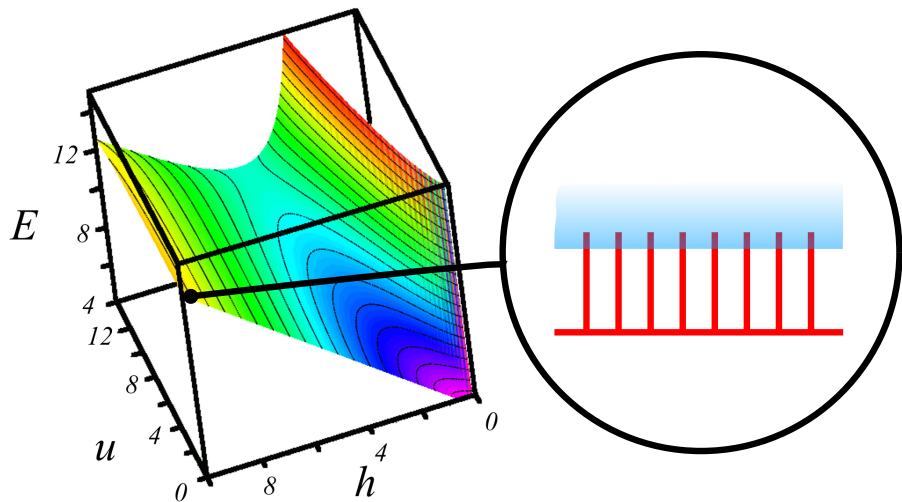
$$u \in \left[0, \frac{L - 2}{2} \right]$$

1D Toy Model II



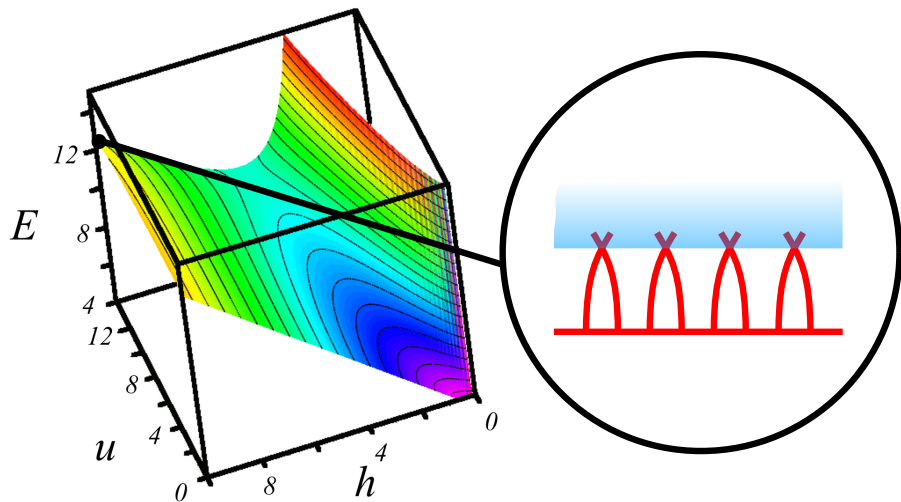
$$k = 1, L = 30, \cos \theta = 1.$$

1D Toy Model II



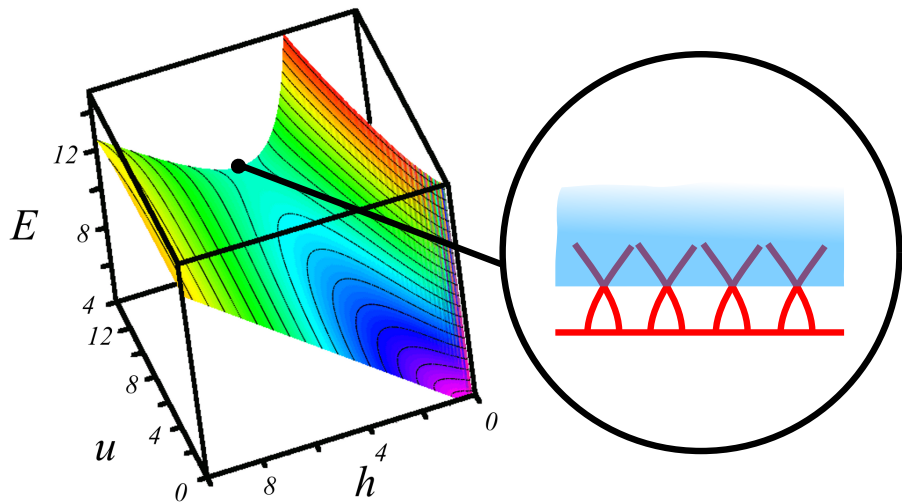
$$k = 1, L = 30, \cos \theta = 1.$$

1D Toy Model II



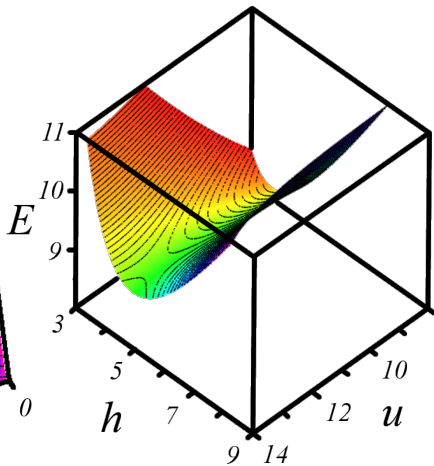
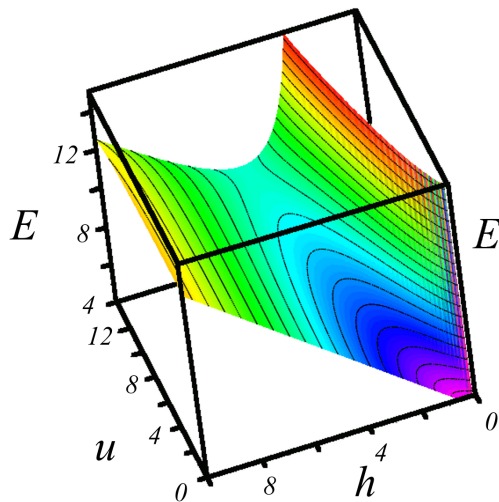
$$k = 1, L = 30, \cos \theta = 1.$$

1D Toy Model II



$$k = 1, L = 30, \cos \theta = 1.$$

1D Toy Model II



$k = 1, L = 30, \cos \theta = 1.$

Estimates for the Lady's Mantle

$(k = 50, \cos \theta = 1/2) \Rightarrow$

$$L \gtrsim 250, h^* \simeq 50!$$

The Theoretical Physicist Problem

What to do if your theory does not agree with the experiments?

Estimates for the Lady's Mantle

$(k = 50, \cos \theta = 1/2) \Rightarrow$

$$L \gtrsim 250, h^* \simeq 50!$$

The Theoretical Physicist Problem

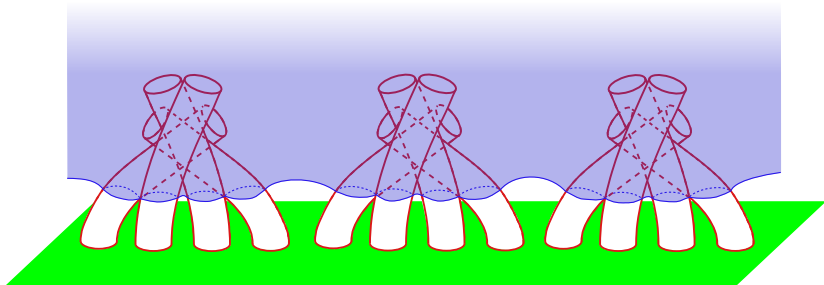
What to do if your theory does not agree with the experiments?

The Panic Model

Assume your model is wrong.

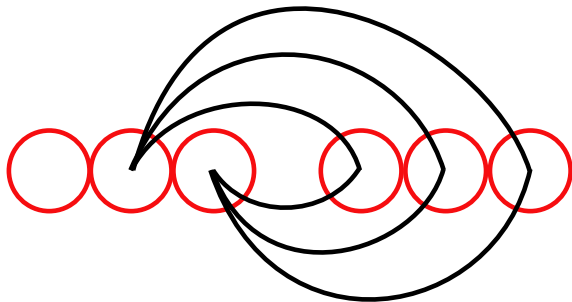
More realistic modeling I

- More than two hairs in a cluster: Even worst conditions.



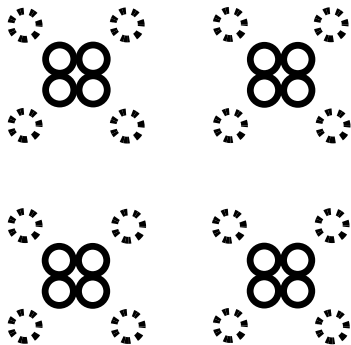
More realistic modeling II

- Pair-wise interactions: Requires hairs with a huge aspect ratio.



More realistic modeling III

- $2D$: Simple model suggests conditions are similar to $1D$.



The Einstein(?) Model

“If the facts don't fit the theory, change the facts.”

Attributed (probably wrongly) to Einstein

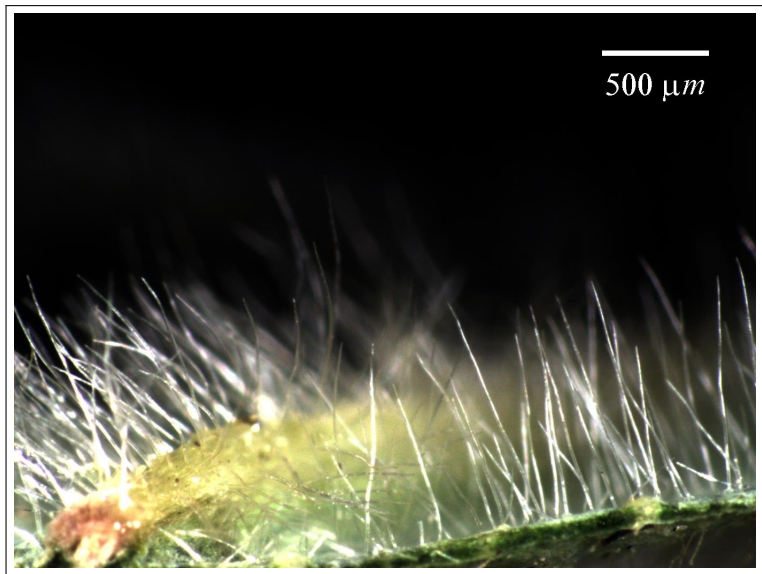
Help from Valentin Blickle



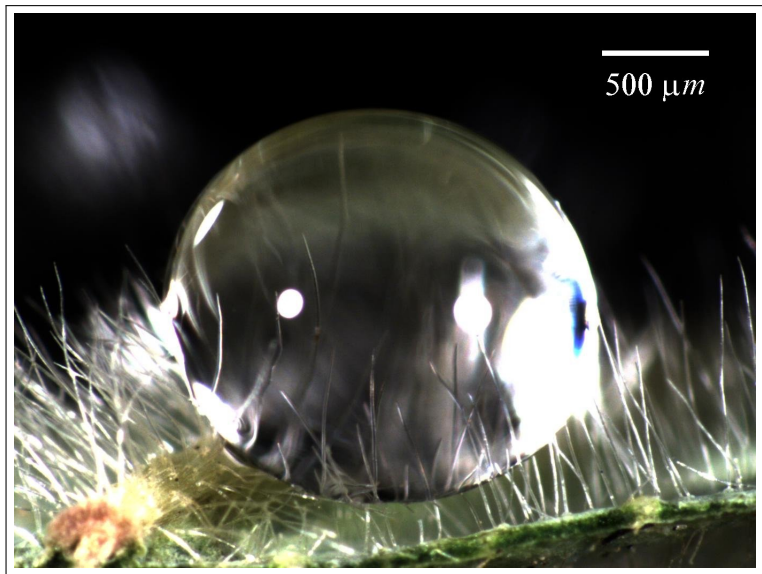
Help from Valentin Blickle



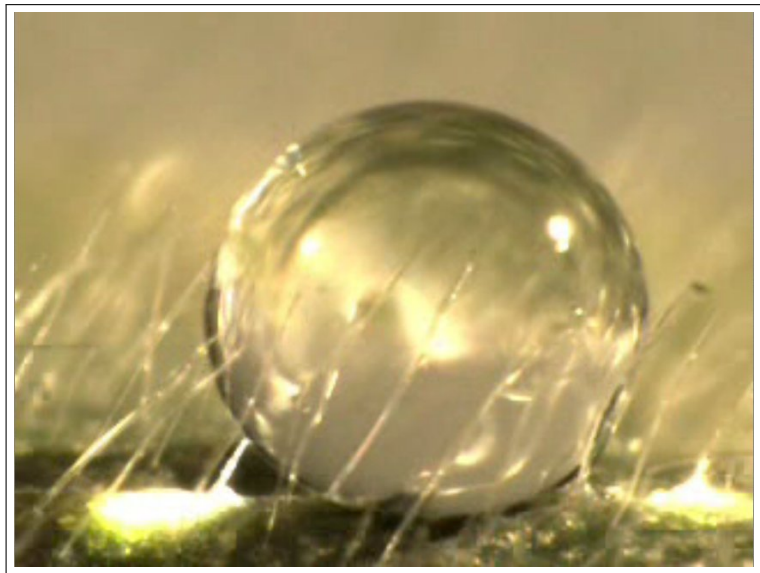
Back to the Lady's Mantle



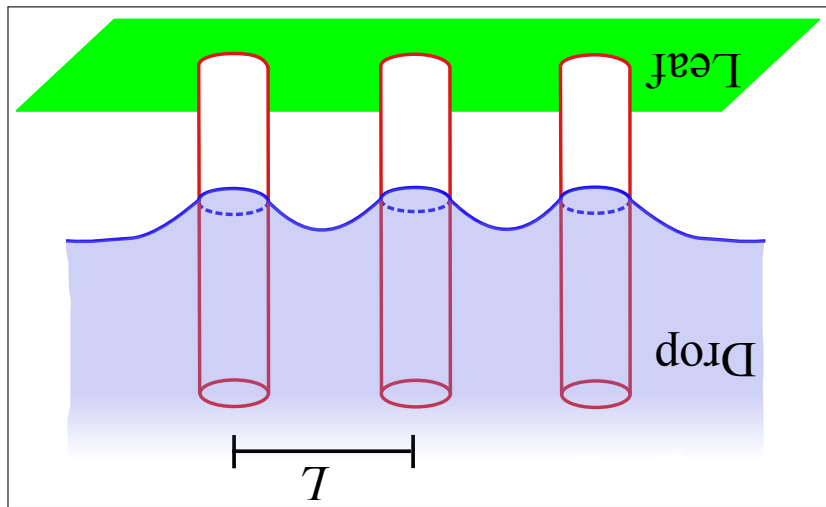
Back to the Lady's Mantle



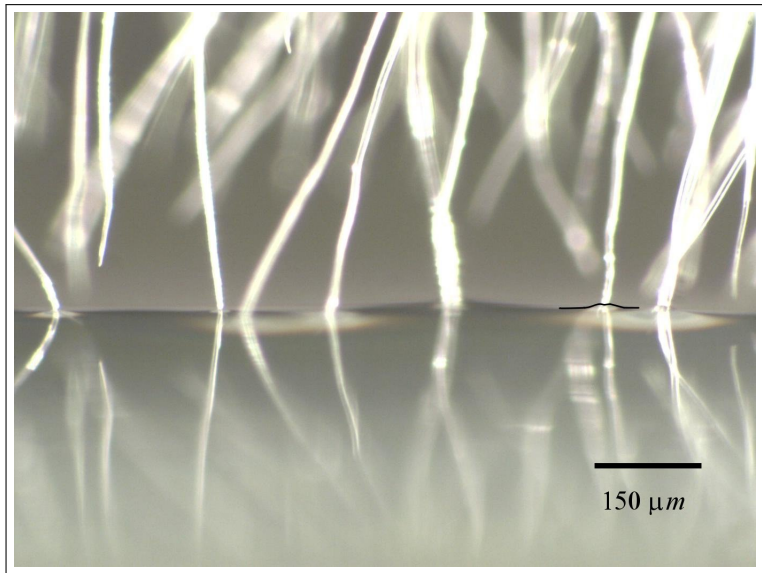
Back to the Lady's Mantle



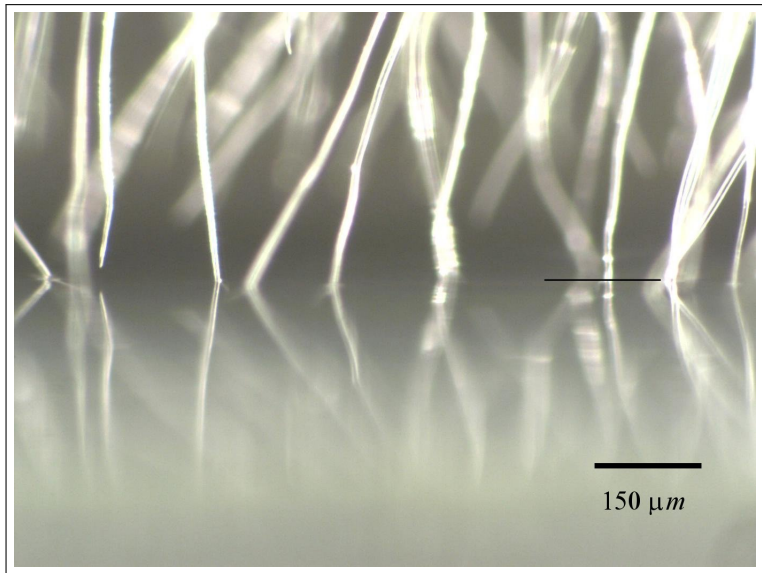
Back to the Lady's Mantle



Back to the Lady's Mantle



Back to the Lady's Mantle



Back to the Lady's Mantle



Grant for a Student in Lisbon

- Before PhD.
- 1 or 2 years.
- Theory and computational work.
- Wetting of patterned substrates by liquid crystals.
- Patchy colloids.
- Nematic emulsions.

Lady's Mantle (*Alchemilla vulgaris*)

“To those who suffer from uncorresponded love, the best is to deposit leaves of this herb on the entrance path to the home of the loved one. But remember, you should deposit them on a New Moon, preferably when the Moon is in Scorpio.”

For those interested

Next New Moon in Scorpio: 6 November 2010, 4:50 GMT.

Lady's Mantle (*Alchemilla vulgaris*)

“To those who suffer from uncorresponded love, the best is to deposit leaves of this herb on the entrance path to the home of the loved one. But remember, you should deposit them on a New Moon, preferably when the Moon is in Scorpio.”

For those interested

Next New Moon in Scorpio: 6 November 2010, 4:50 GMT.