Droplet manipulation on fiber networks

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Introduction

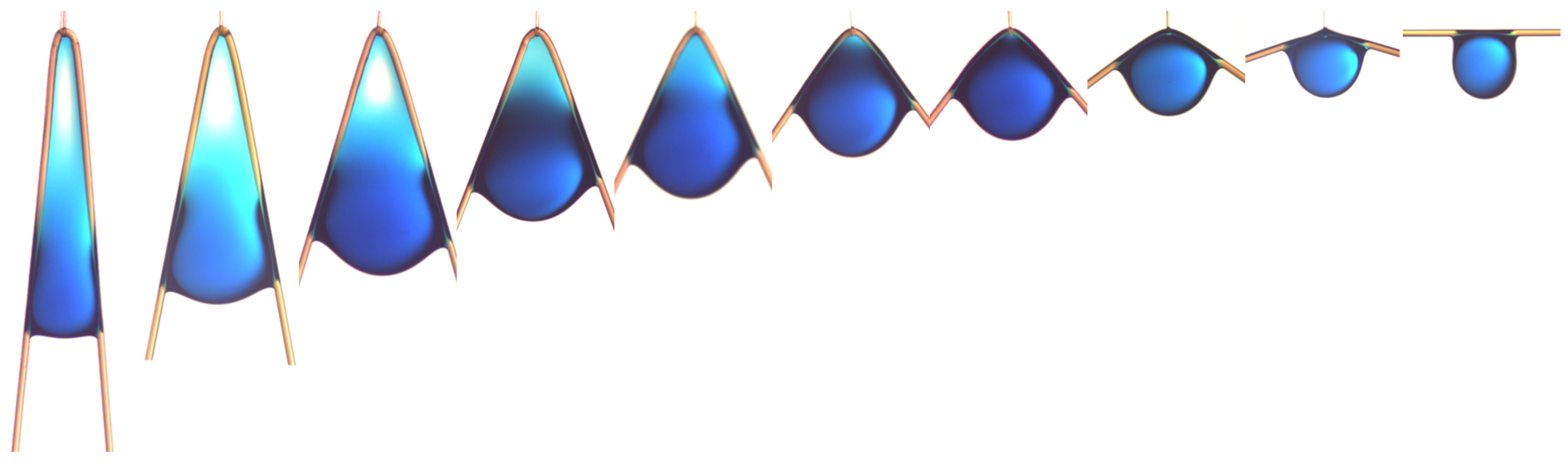
Droplets on fibers are part of our everyday lives. From the droplets trapped on a spider web to the ones stuck on cactus spines or even the ones caught on a dog's fur, all these situations are really common phenomena.

In nature, specific structures are able to hold large droplets. As shown in the picture, a water droplet of about 60 µl is trapped on the interior fork of juniper tree leaves. This observation implies that by simply changing the geometry of a fiber, the volume of the water stuck in the structure can be increased.

In this work, we focus on a fundamental question : **how much liquid can be held by a bent fiber?**

Experimental setup

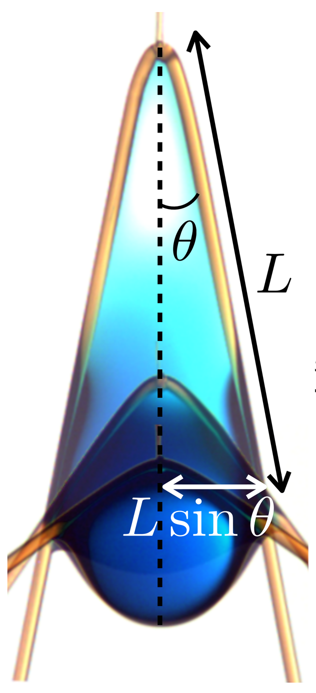
Nylon fibers of three different diameters, namely 160 µm, 250 µm and 350 µm, are used. They are bent with a half-angle, θ , ranging from 0° up to 90°. A soapy water droplet is placed on the vertex and its volume is gradually increased until the droplet detaches. The picture below shows the maximal volumes reached for various angles.



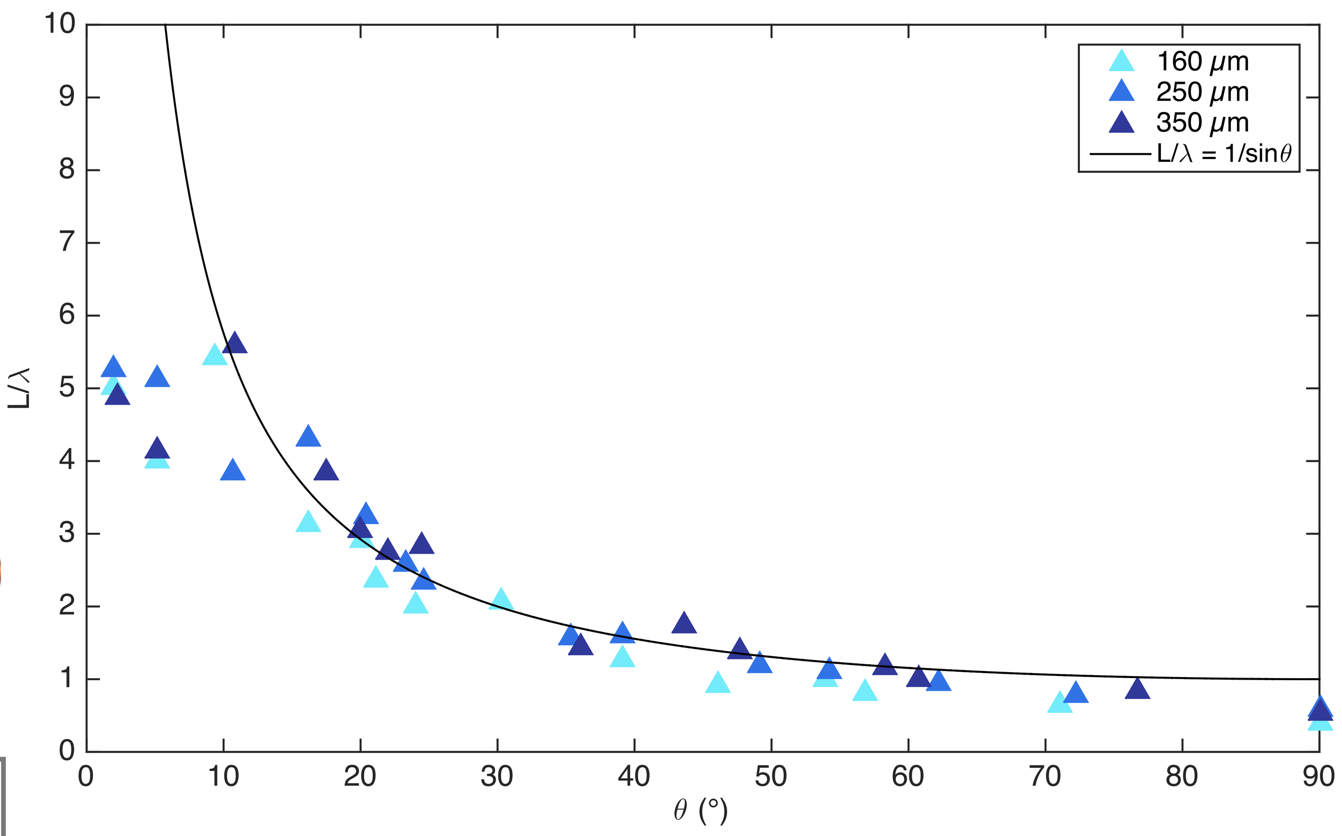
The **maximal volume** before detachment, Ω , **seems to strongly depend on the angle.** An optimal volume can be reached for a half-angle close to 20°. The experimental data are represented on the right.

Wetting length

For each configuration, the wetting length of the droplet along the fiber, L, is measured. Based on our experiment data, we proposed that $L\sin\theta/\lambda \approx 1$ meaning that the **characteristic length** of the drop-fiber system ($L\sin\theta$) is **comparable** to the **characteristic capillary length** of the liquid ($\lambda = \sqrt{\gamma/\rho g}$) for $\theta > 20°$.

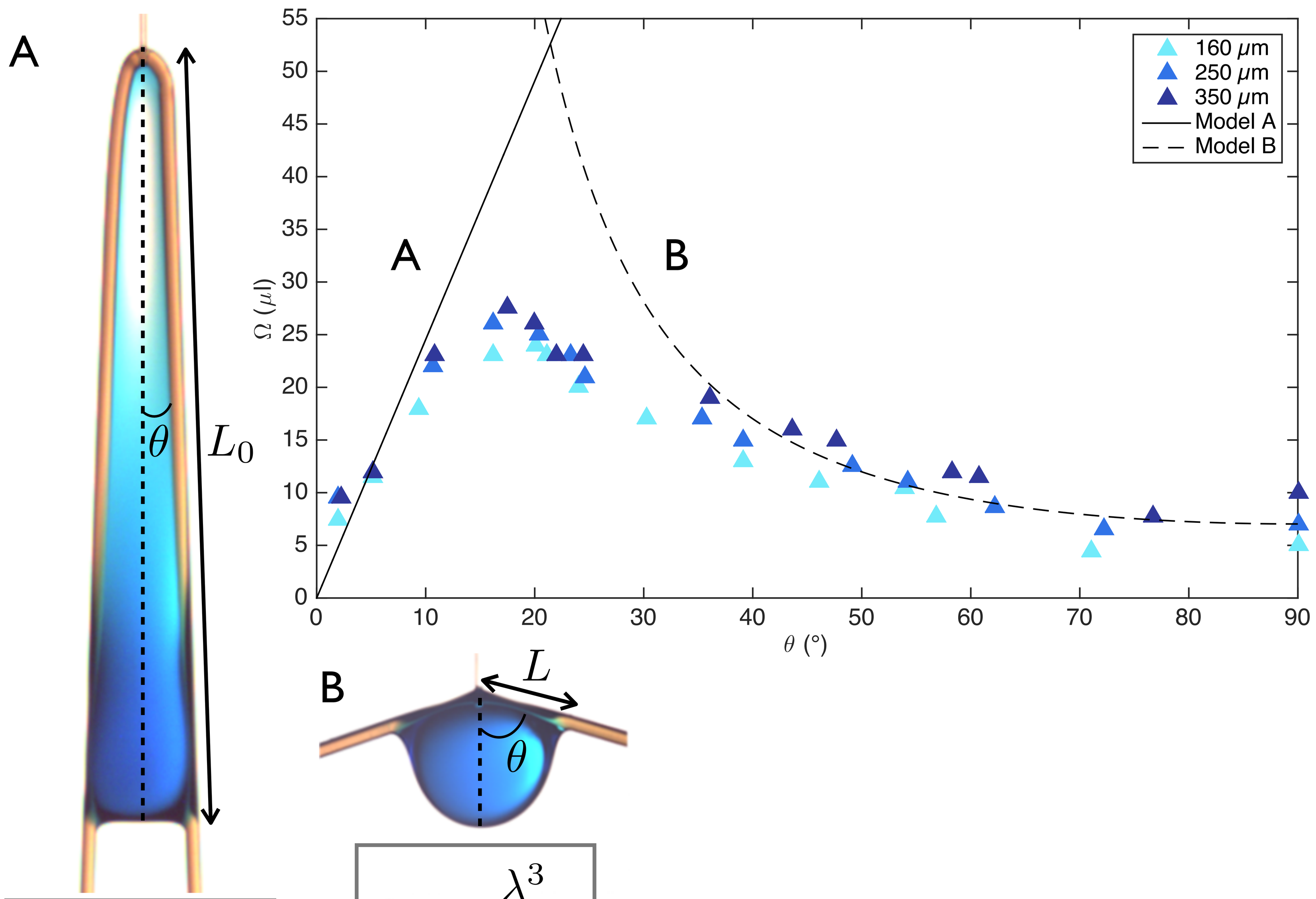


$L\sin\theta \approx \lambda$



Models

Although the case of a droplet hanging on a horizontal fiber has been studied by Lorenceau *et al.* (2004), there is no **model for a droplet trapped on a bent fiber.** Here, we propose models based on **the total free energy** of the system. We have to distinguish two regimes, A and B : one for small angles ($\theta < 20°$) and another for large angles ($\theta > 20°$). In the **regime A**, the bottom part of the droplet is held by a **soapy film** created in the upper part. In the **regime B**, we consider that the droplet remains on the fiber thanks to the **capillary forces** applying along the fiber.

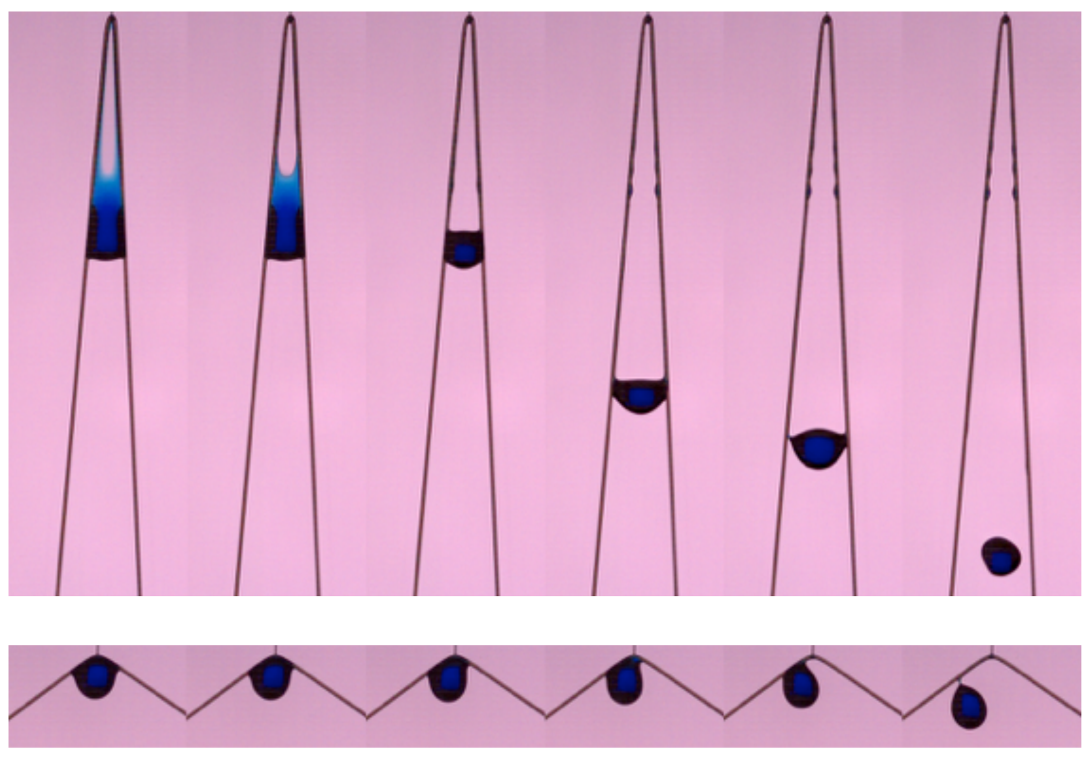


$\Omega = 4\lambda^2 L_0 \theta$

$\Omega = \dfrac{\lambda^3}{\sin^2\theta}$

Detachment process

Depending on the regime, the **detachment process** is different. In **regime A**, the **soapy film breaks** and the droplet remains in contact with both branches until it detaches. Whereas, in **regime B**, the **droplet moves off the center** of the corner and slides along one branch of the bent fiber.



Conclusion and perspectives

We showed that **bent fibers** are able to **hold larger droplets** than horizontal fibers. We proposed two different models to predict the maximal volume. We highlighted a difference between the two regimes during the detachment process. Finally, this study explains why some plant structures are able to hold large droplets. These results can be used to improve the **fog collection process**.

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