Honey coils

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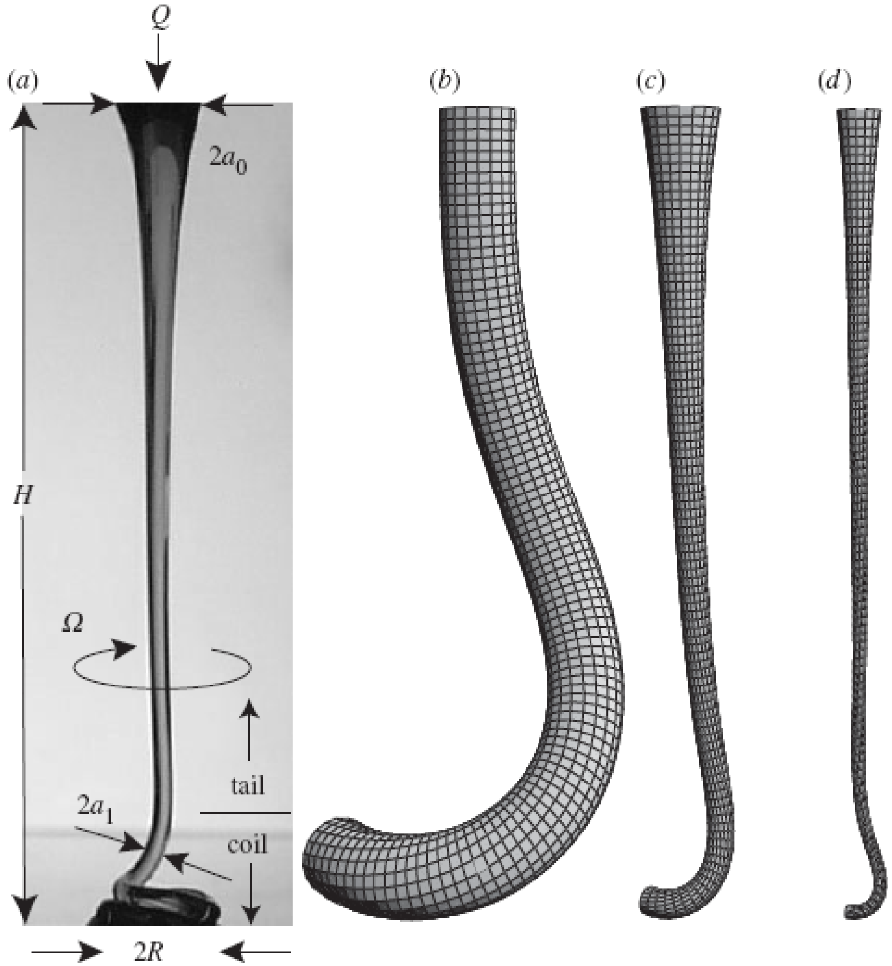
The problem

A thin, downward flow of viscous liquid, such as honey, often turns itself into circular coils. Study and explain this phenomenon.

Previous investigations



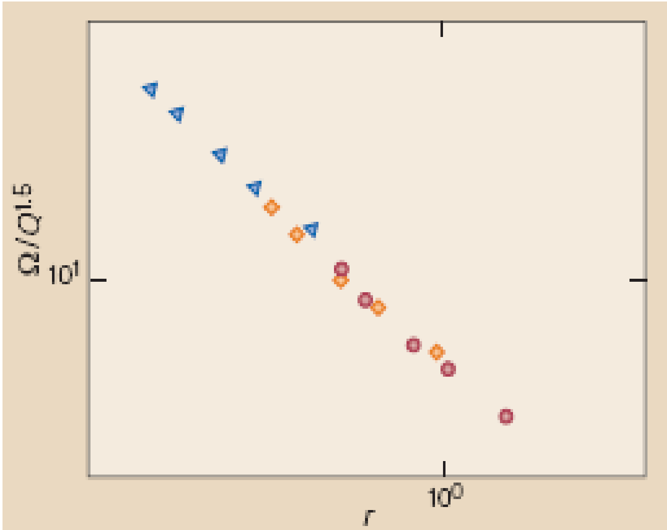


Figure 2 Log–log plot of the normalized coiling frequency ($\Omega/Q^{1.5}$) against filament radius (r). Triangle: hole radius, 3.2 mm, Q=0.56 g s^{-1}; diamond: hole radius, 4.0 mm, Q =0.96 g s^{-1}; circle: hole radius, 4.8 mm, Q=1.28 g s^{-1}. The data are fitted by the relation $\Omega/Q^{1.5} \sim r^{-3.58}$ for each flow rate, and confirm equation (2).

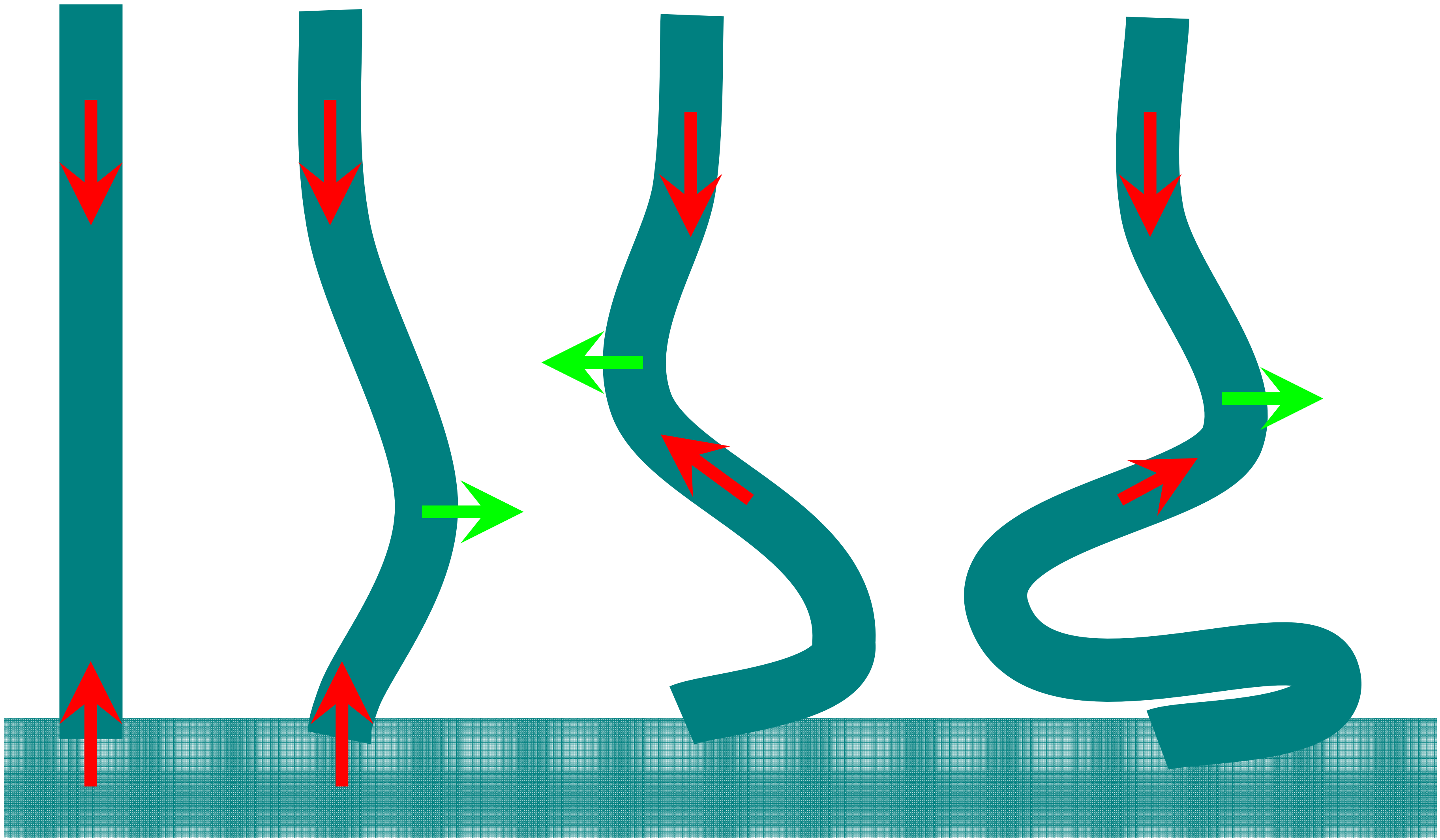
Barnes G., Woodcock R. (**1958**) “Liquid rope-coil effect”. *Am. J. Phys*. **26**, 206–210.
Mahadevan L. at al. (**2000**) “Fluid rope trick investigated” Nature **392**, 140
Ribe N. M. (**2004**) “Coiling of viscous jets”. *Proc. R. Soc. Lond.* A **460**, 3223–3239.

Buckling, folding and coiling

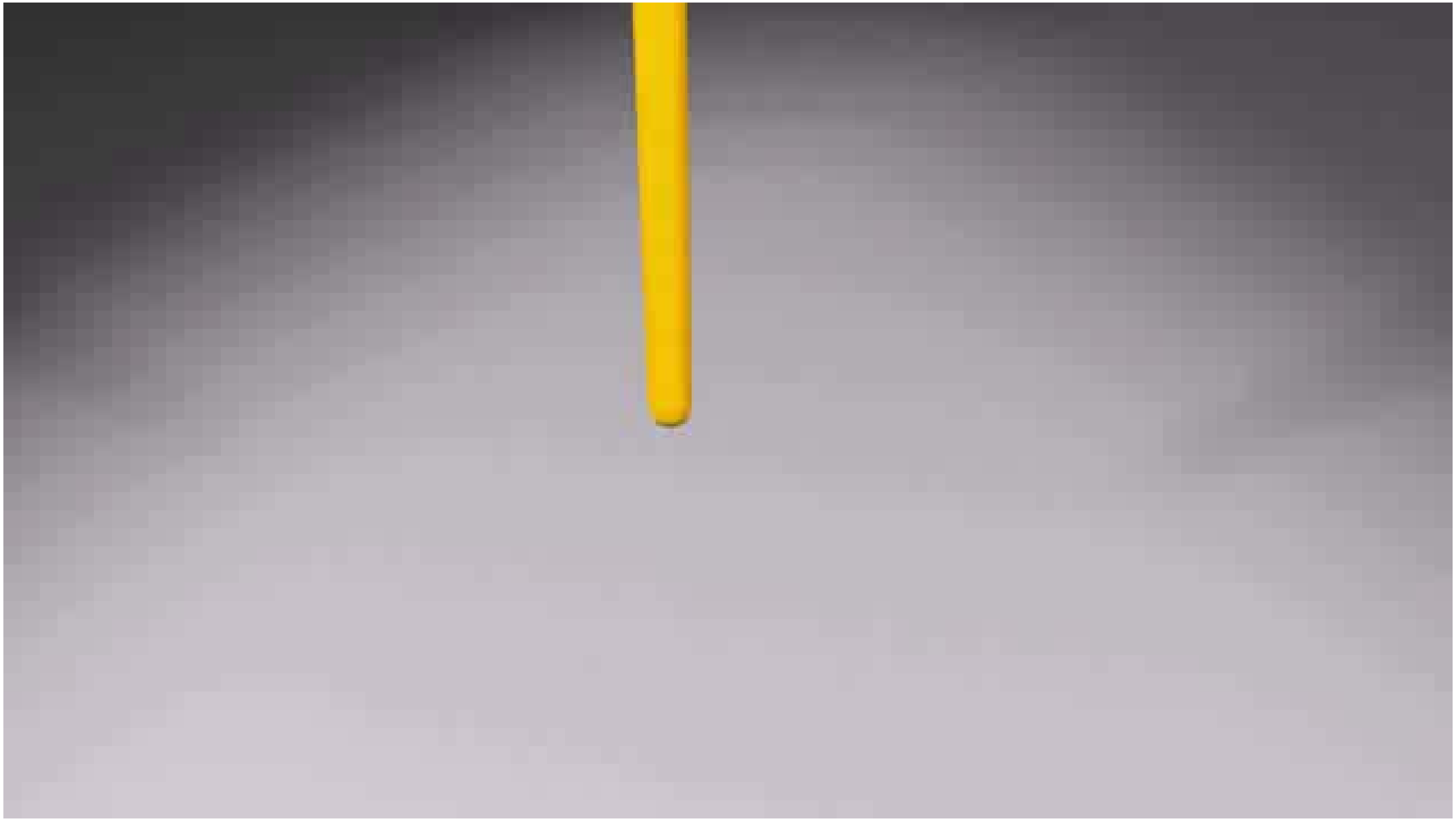
Obtaining a viscous sheet (video)

Folding of a viscous sheet (video)

Folding of a viscous sheet



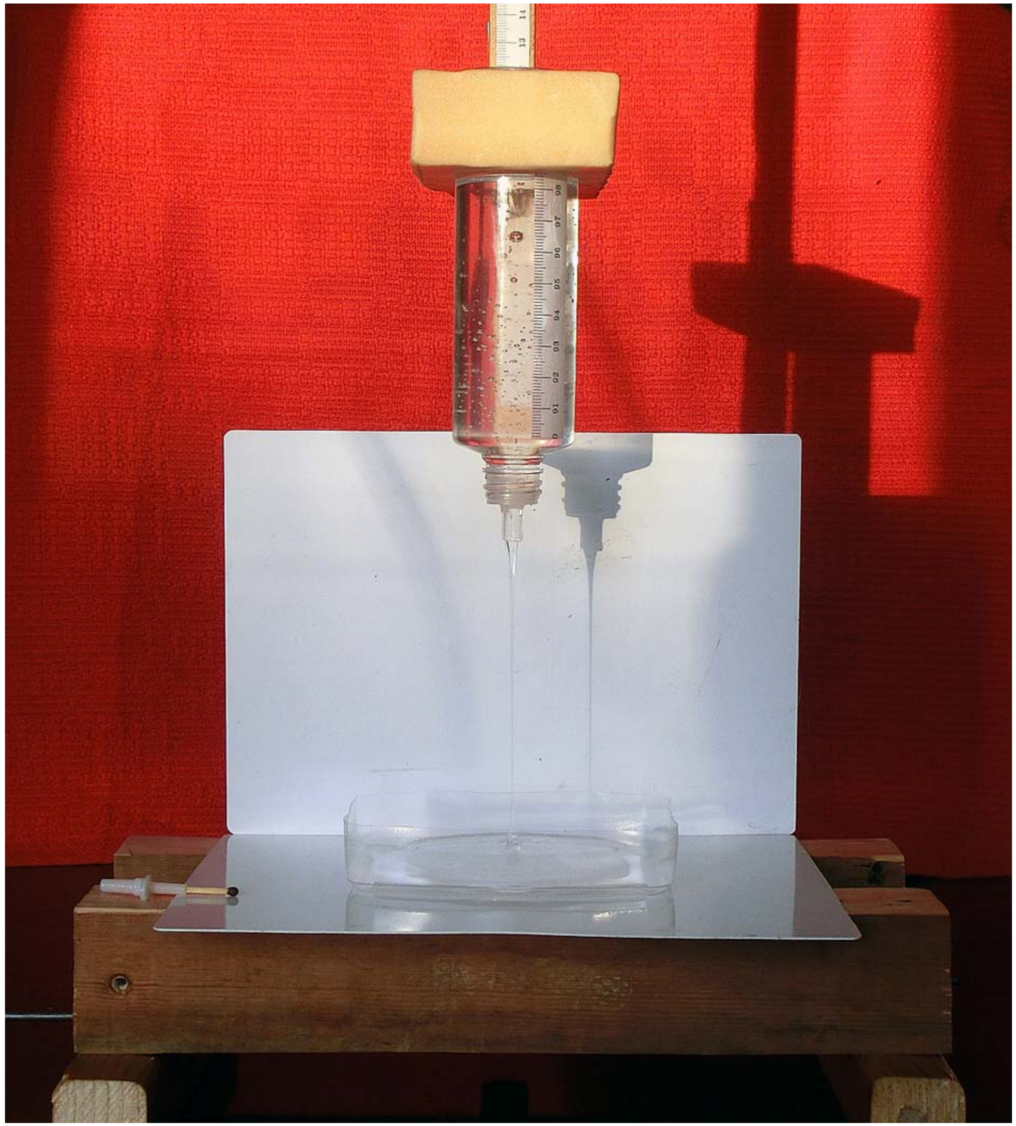
Coiling of a viscous jet (video)



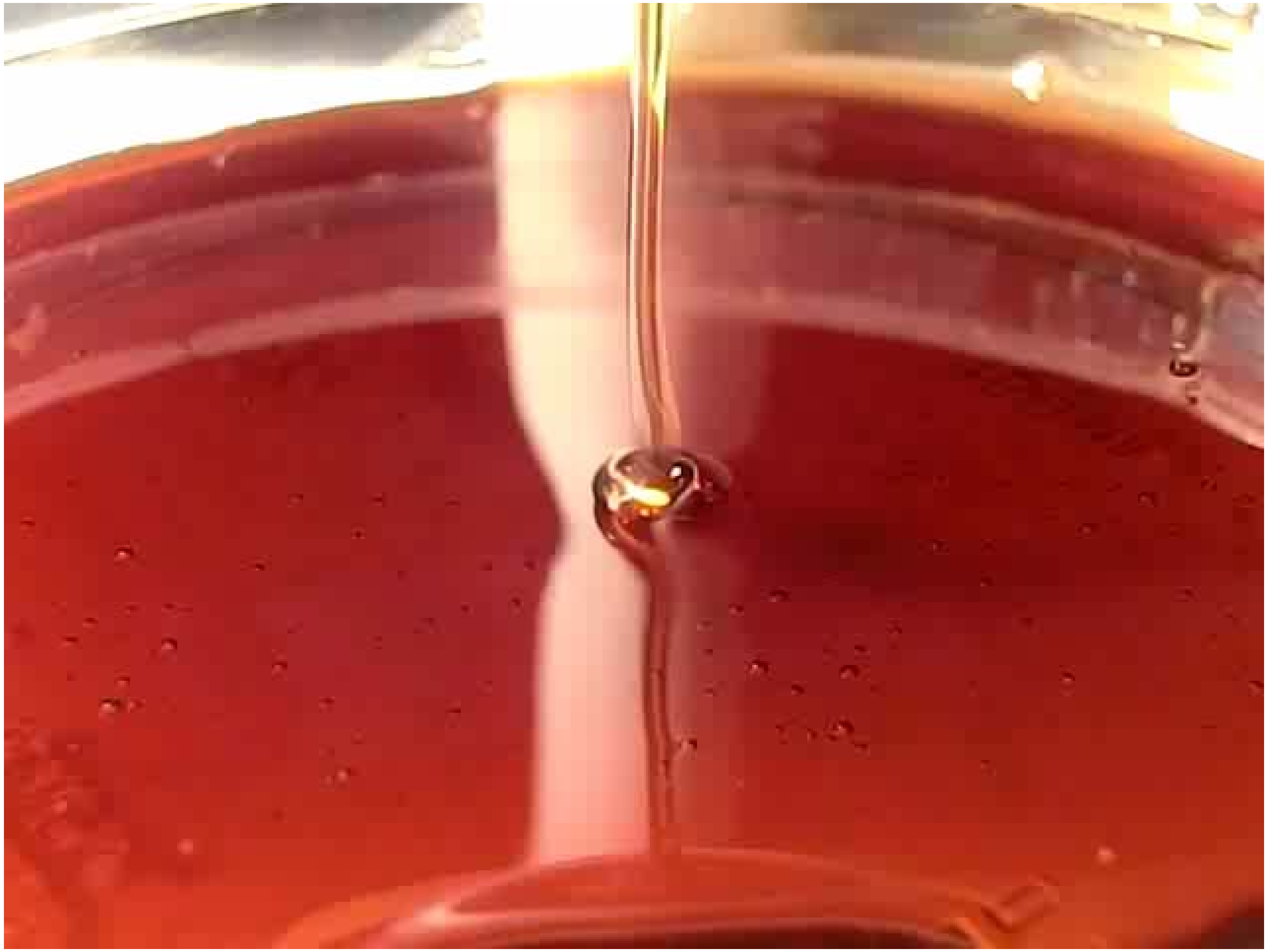
Computer simulation by Ch.Batty & B.Houston (2011)

Choice of fluid

Experimental setup



Experiment with honey (video)

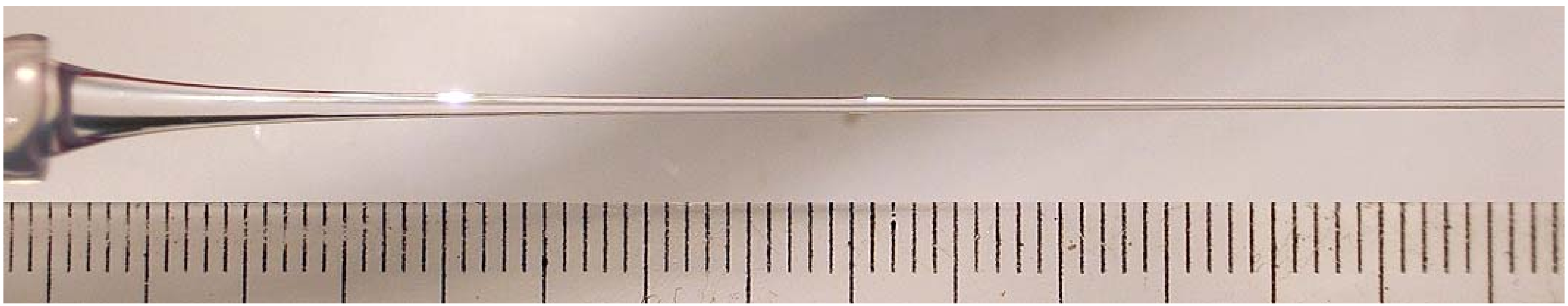


Silicon oil PMS-10000

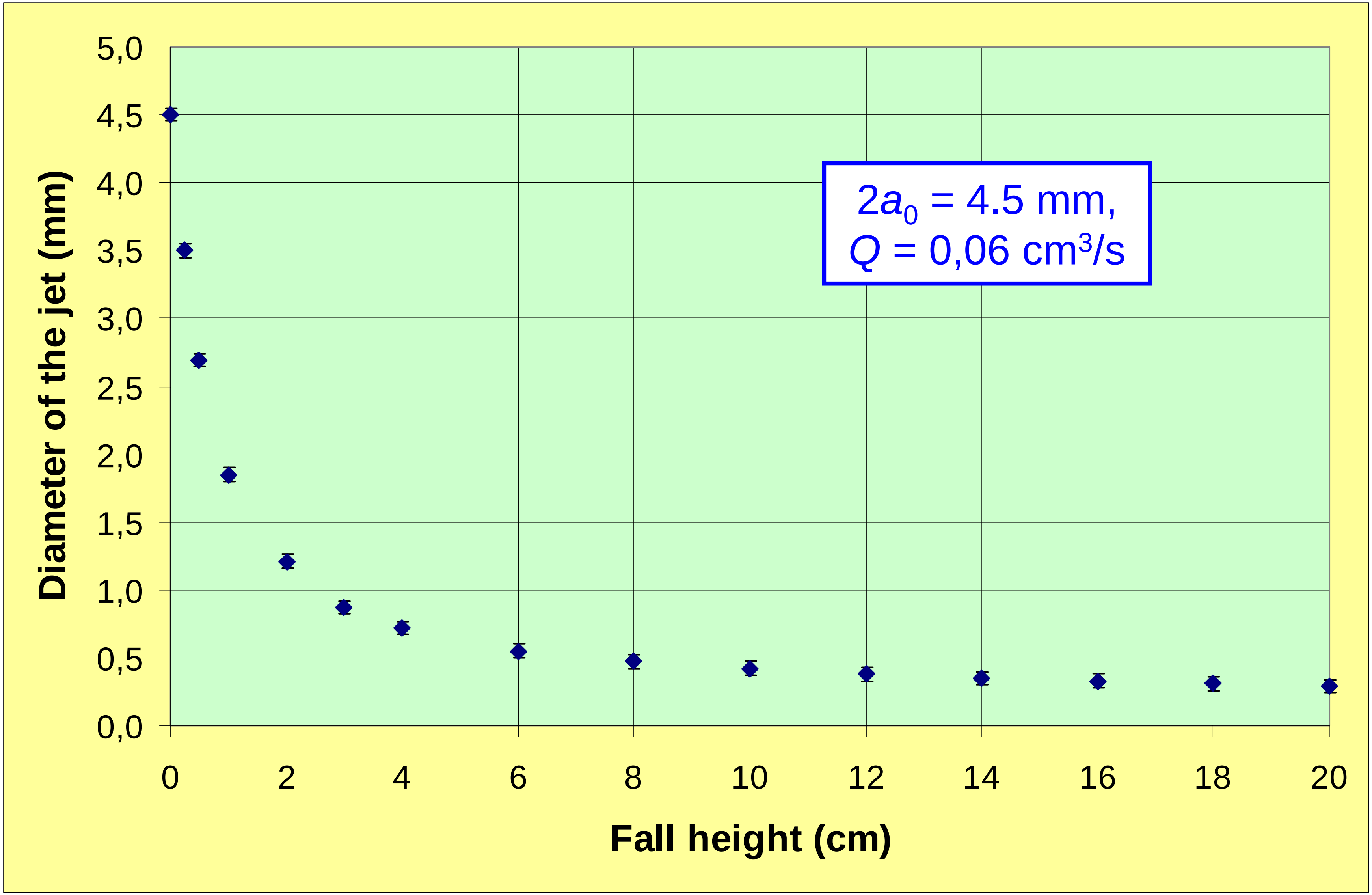
- Dynamic viscosity of this fluid is 10000 times more than of water.
- Density 980 kg/m^3

Shape of the jet

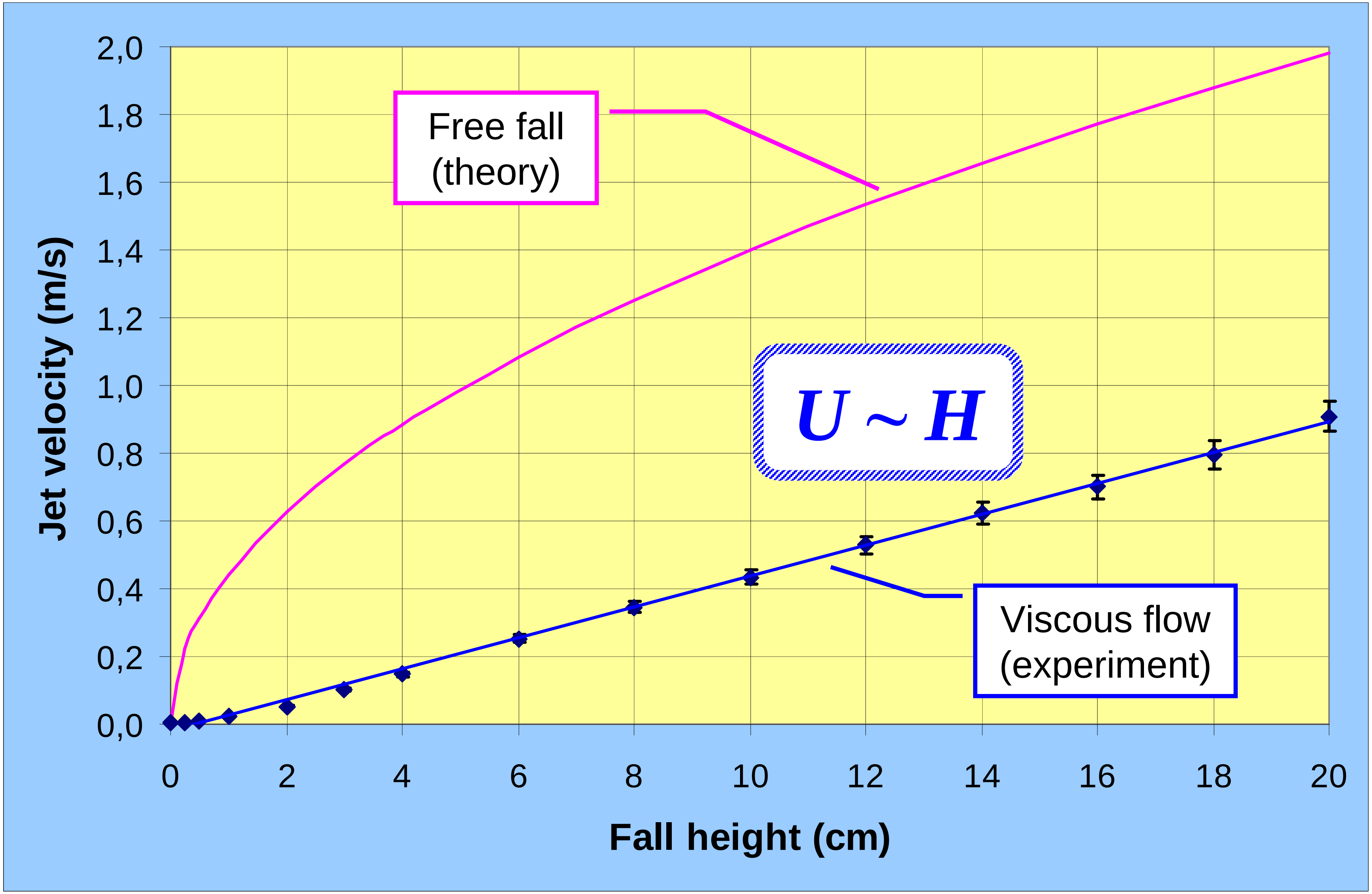
Shape of the jet



Shape of the jet



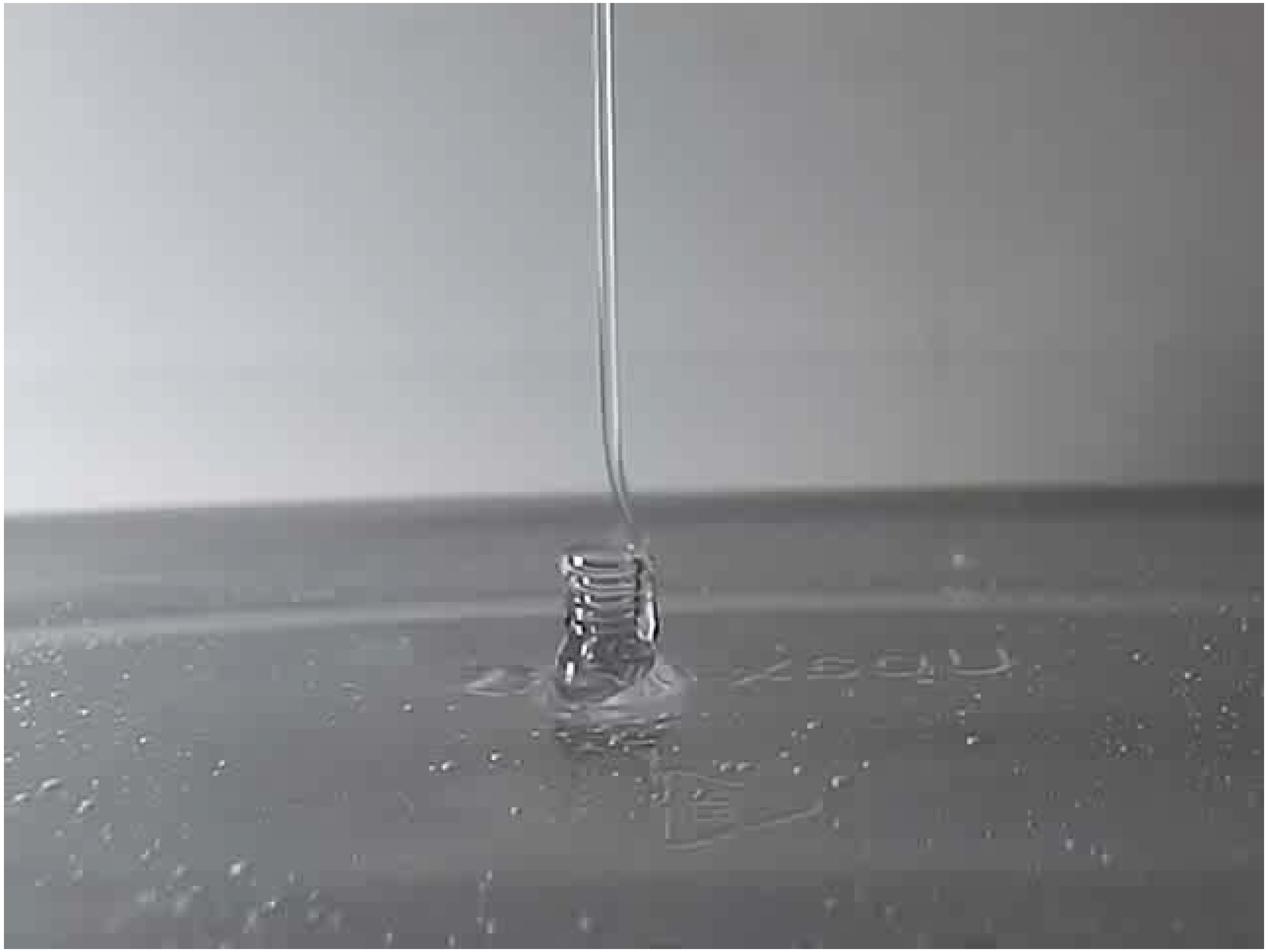
The viscous flow and the free fall



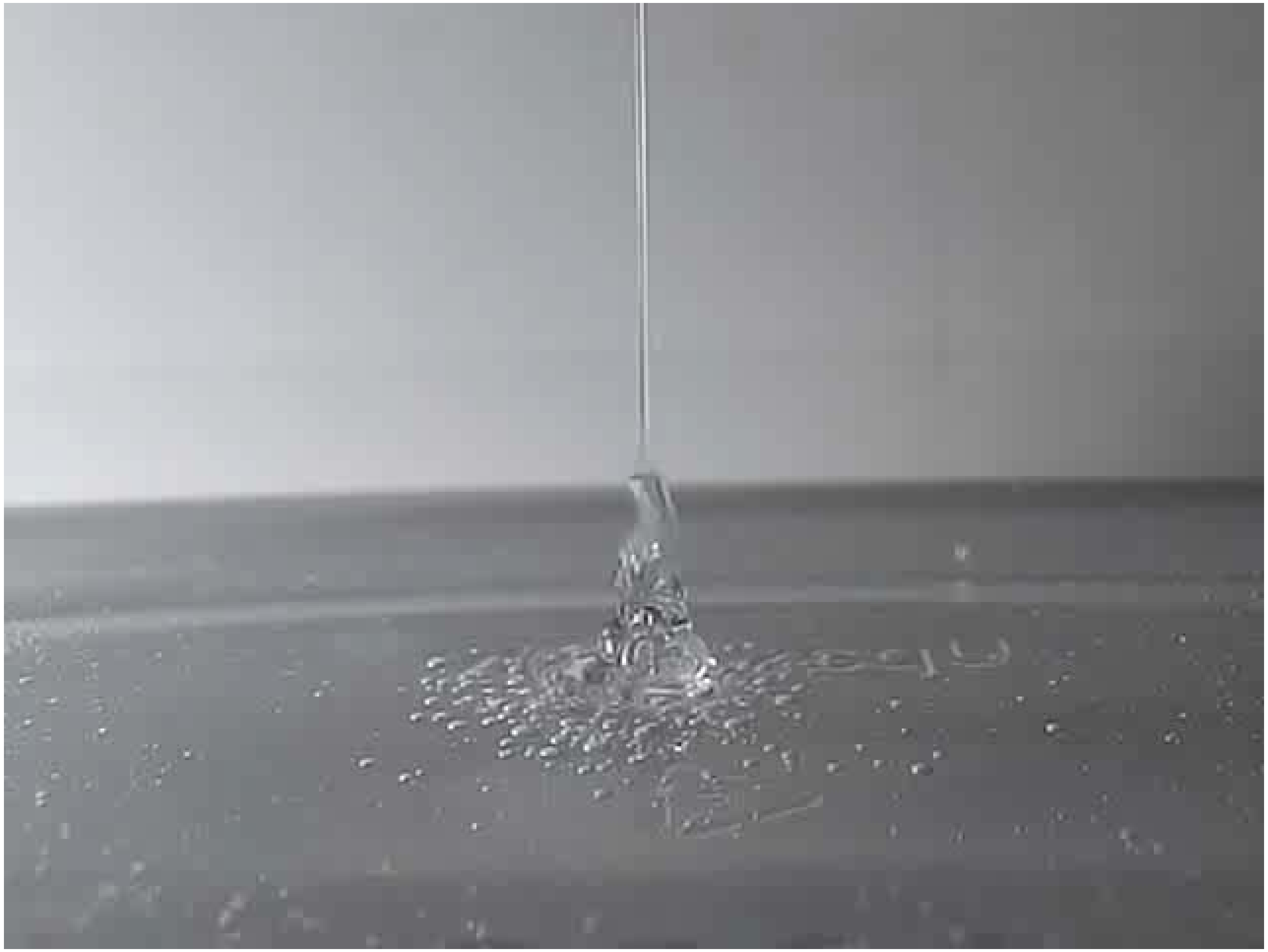
Coiling experiment

Height 2 cm (video)

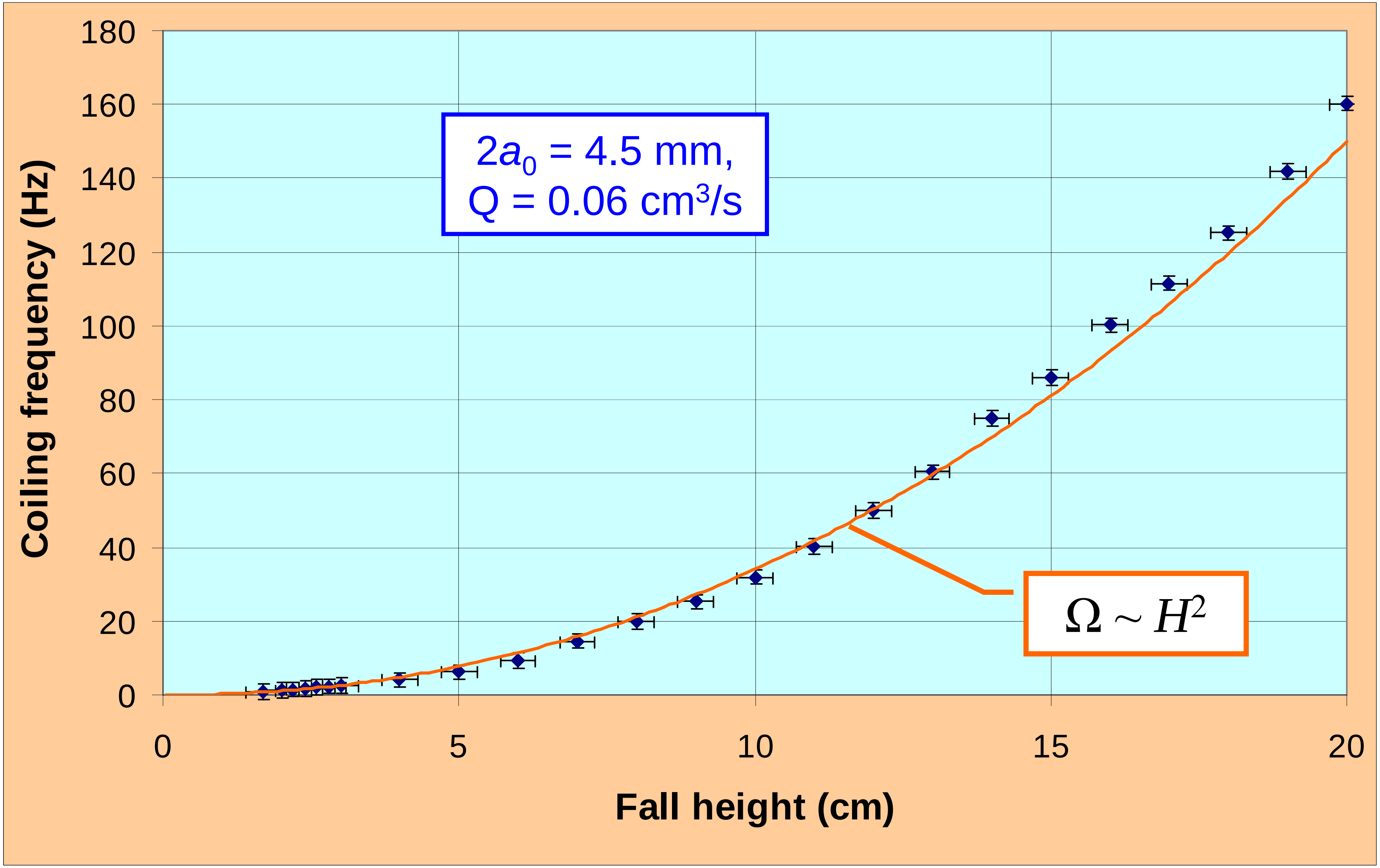
Height 8 cm (video)



Height 15 cm (video)

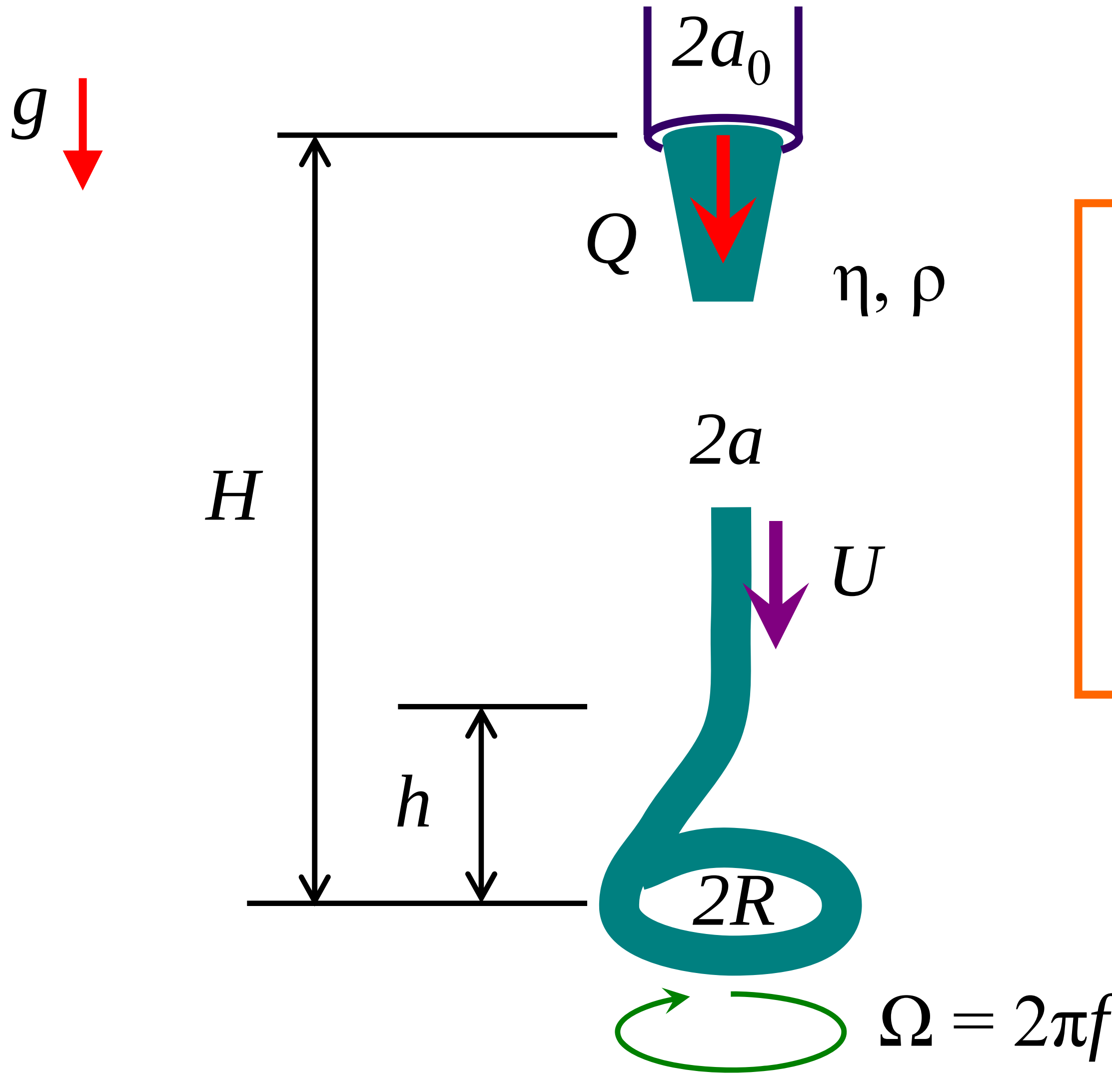


Coiling frequency vs. fall height



Theoretical model

Parameters of the jet and the coil



$$Q = \pi a^2 U$$

$$\Omega = \frac{U}{R}$$

Scaling of coiling frequency

$$\rho a^2 R \cdot \Omega U \sim \eta a^2 \frac{U}{R}$$

Mass · Acceleration ~ Viscous force

$$\Omega \sim \frac{\eta}{\rho R^2} \sim \frac{\eta \Omega^2}{\rho U^2}$$

$$\Omega \sim \frac{\rho U^2}{\eta}$$

Neglected forces

~~Surface tension~~

~~Gravity~~

Current results

Theory of a jet coiling:

$$\Omega \sim U^2$$

Experiment with a falling jet:

$$U \sim H$$

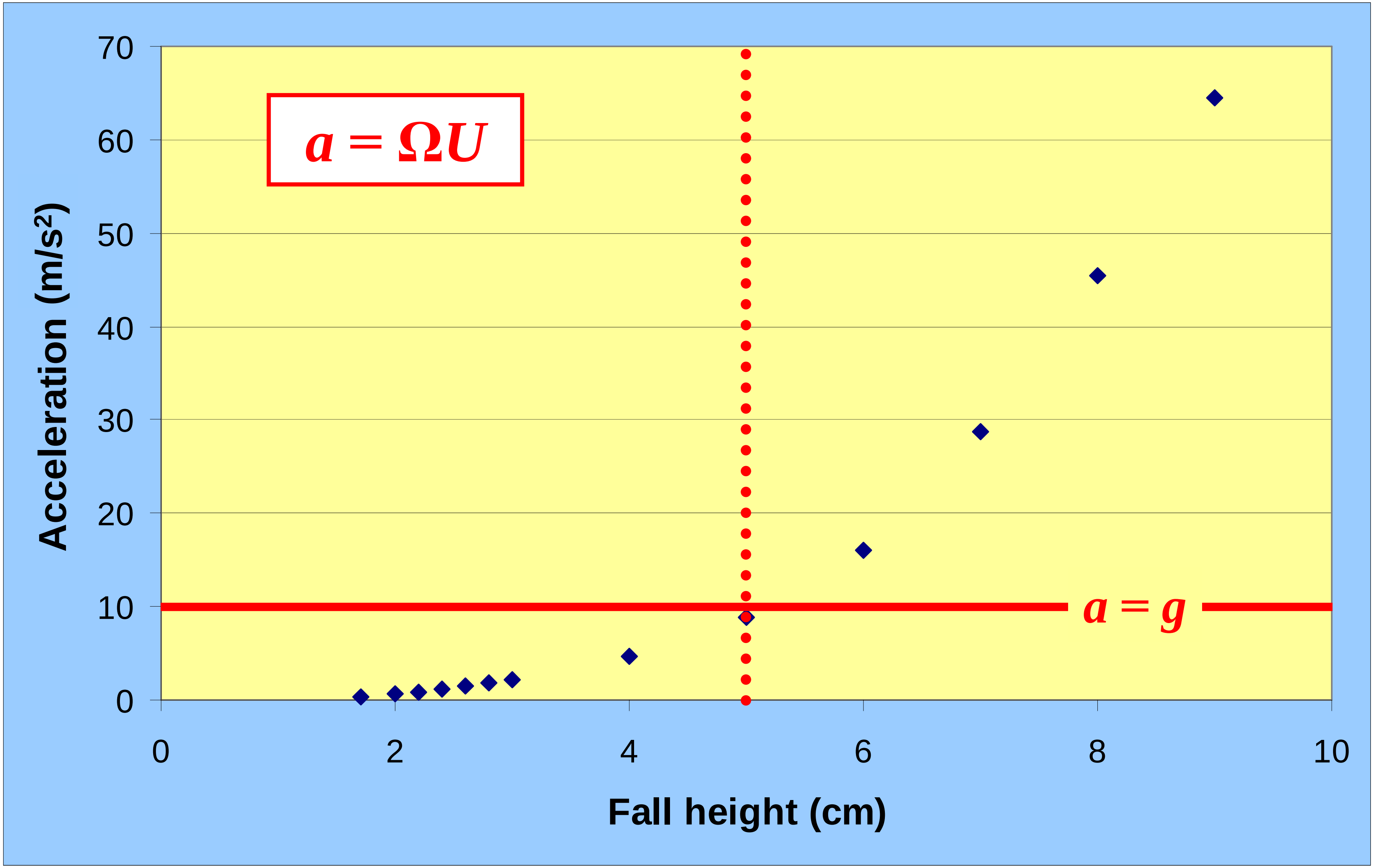
Experiment with a jet coiling:

$$\Omega \sim H^2$$

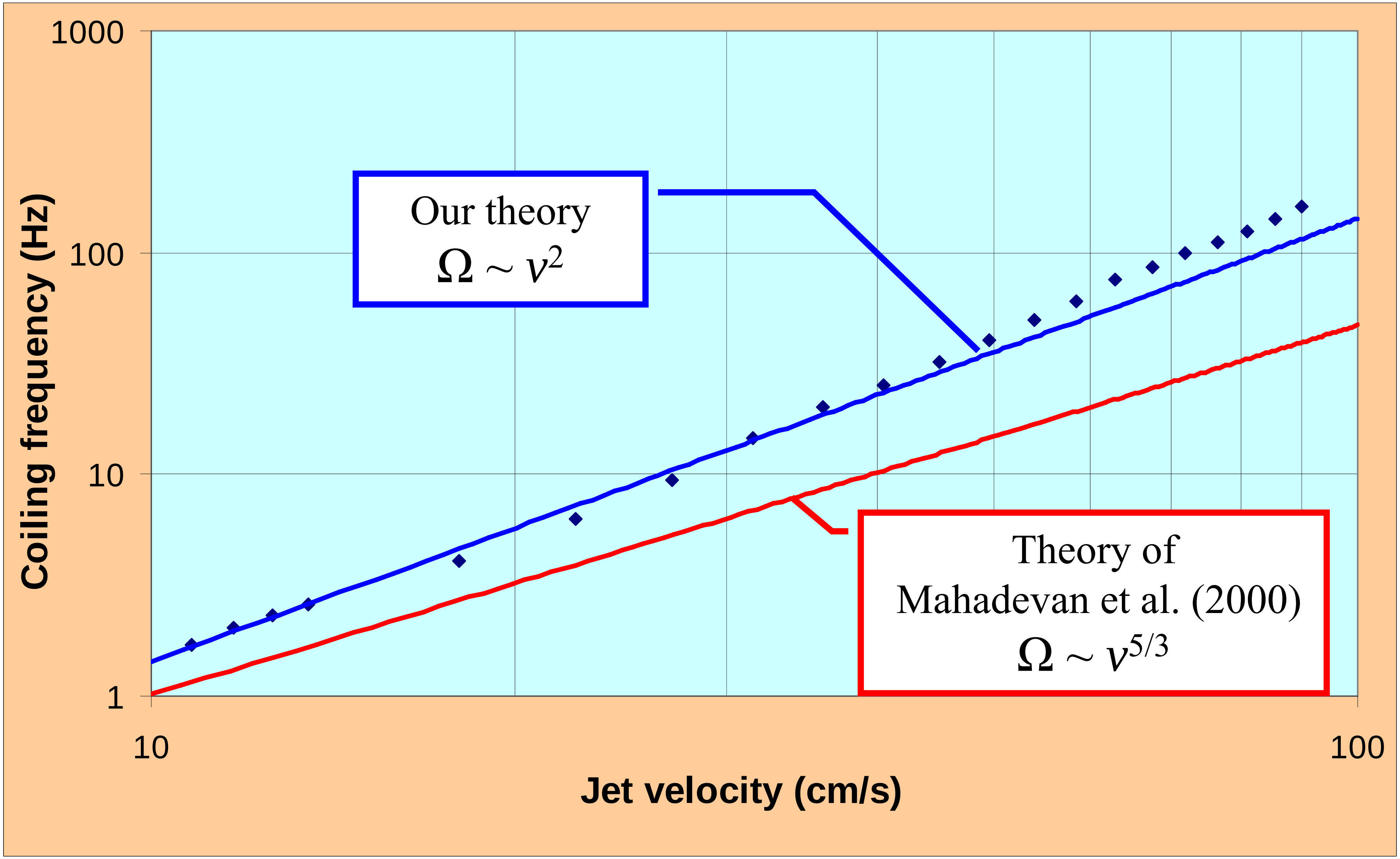
The theory is consistent with the experiment

Additions

Gravity neglecting



Comparison with Mahadevan theory



Summary

Conclusions

- Coiling of a viscous jet is explained by the interplay of viscous and inertial forces.
- Our theoretical model predicts that coiling frequency of viscous jet is proportional to the square of jet velocity.
- Our experiment shows a good agreement with this prediction.

References

- Barnes G., Woodcock R. (1958) “Liquid rope-coil effect”. *Am. J. Phys*. **26**, 206–210.
- Mahadevan L., Ryu W.S., Samuel A.D.T. (1998) “Fluid rope trick investigated”. *Nature* **392**, 140. Correction: 2000, **403**, 502.
- Ribe N. M. (2003) “Periodic folding of viscous sheets”. Phys. Rev. E, **68**, 036305.
- Ribe N. M. (2004) “Coiling of viscous jets”. *Proc. R. Soc. Lond.* A **460**, 3223–3239.

Thank you for your attention!