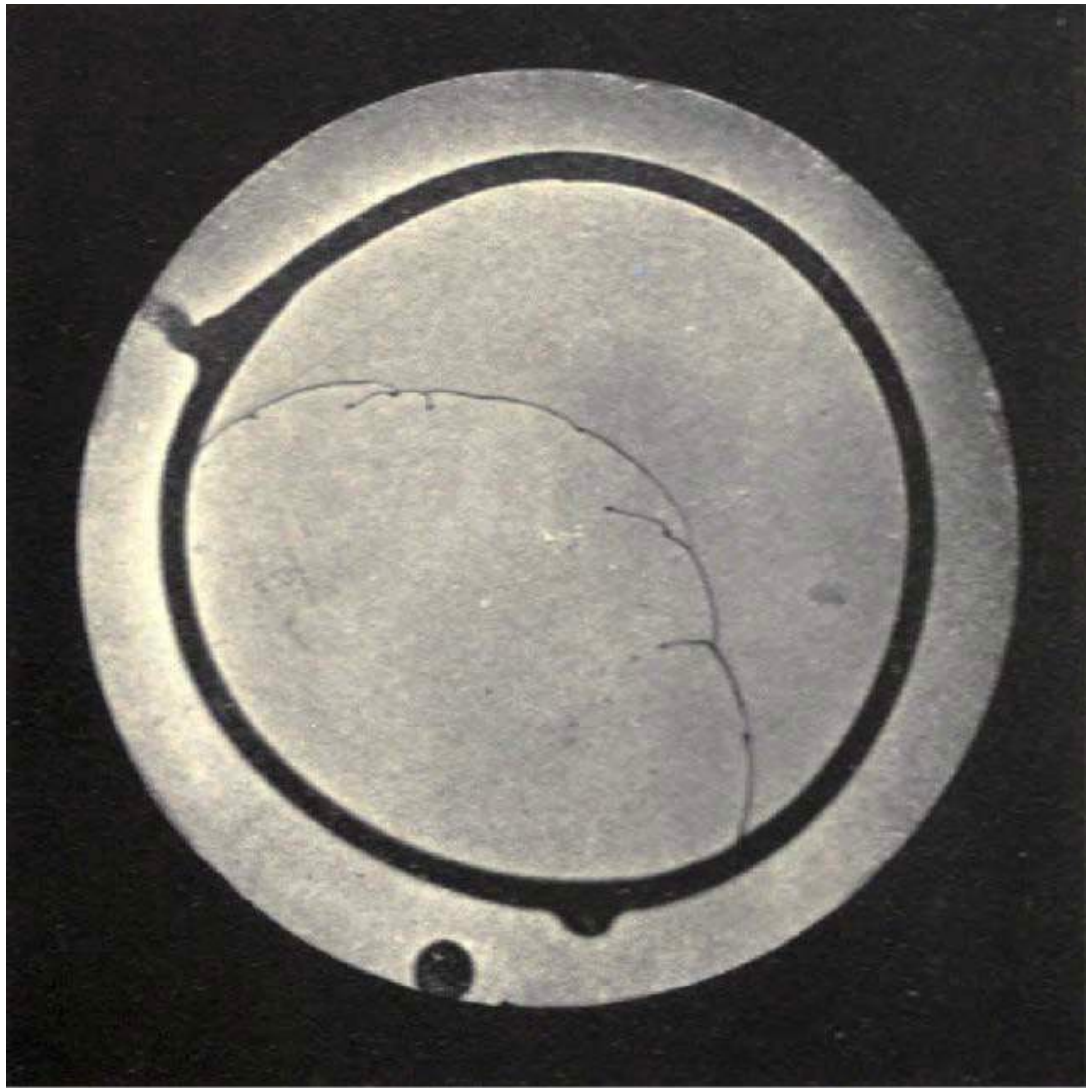
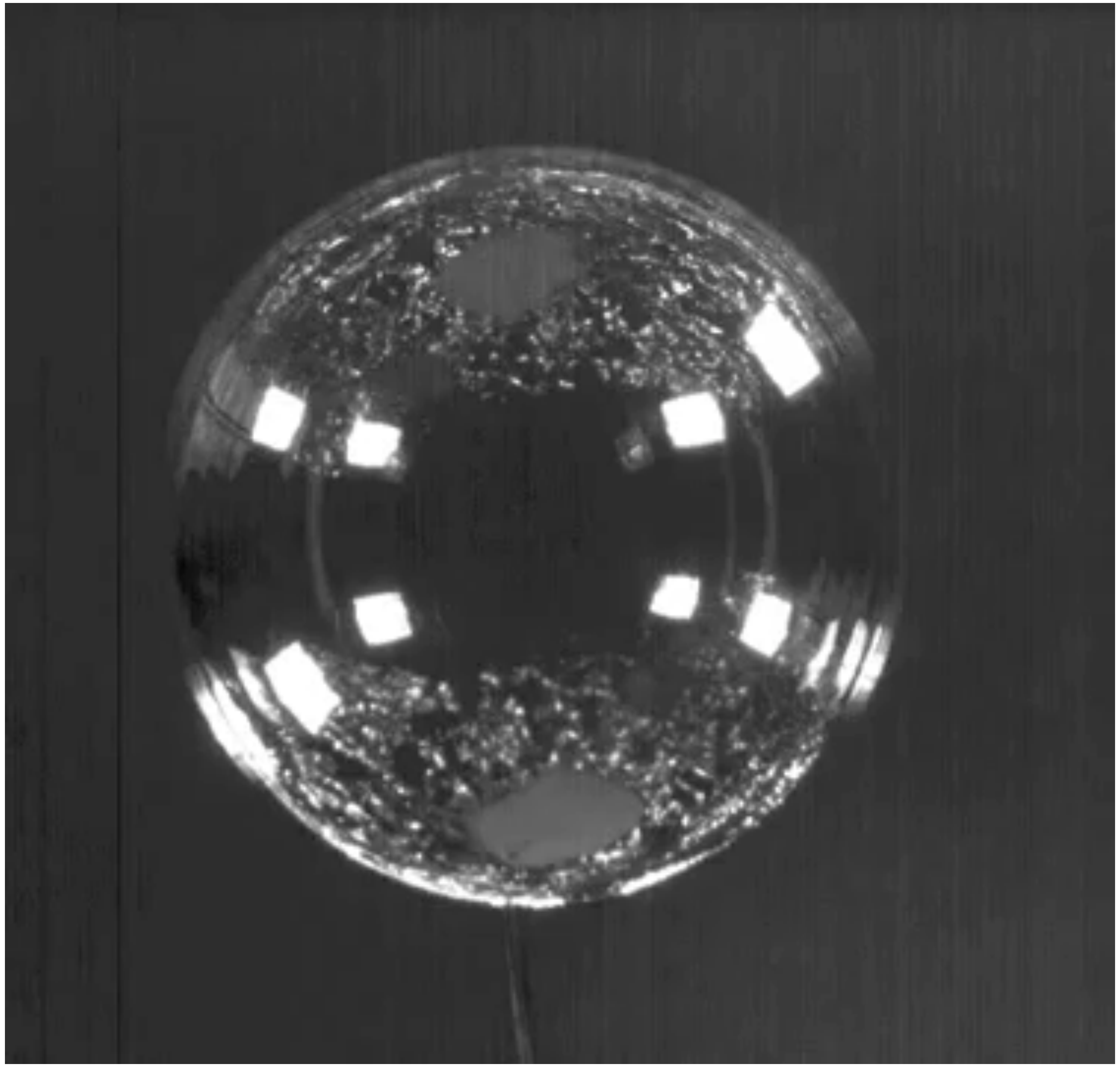
Figure 7

Taylor–Culick Retractions

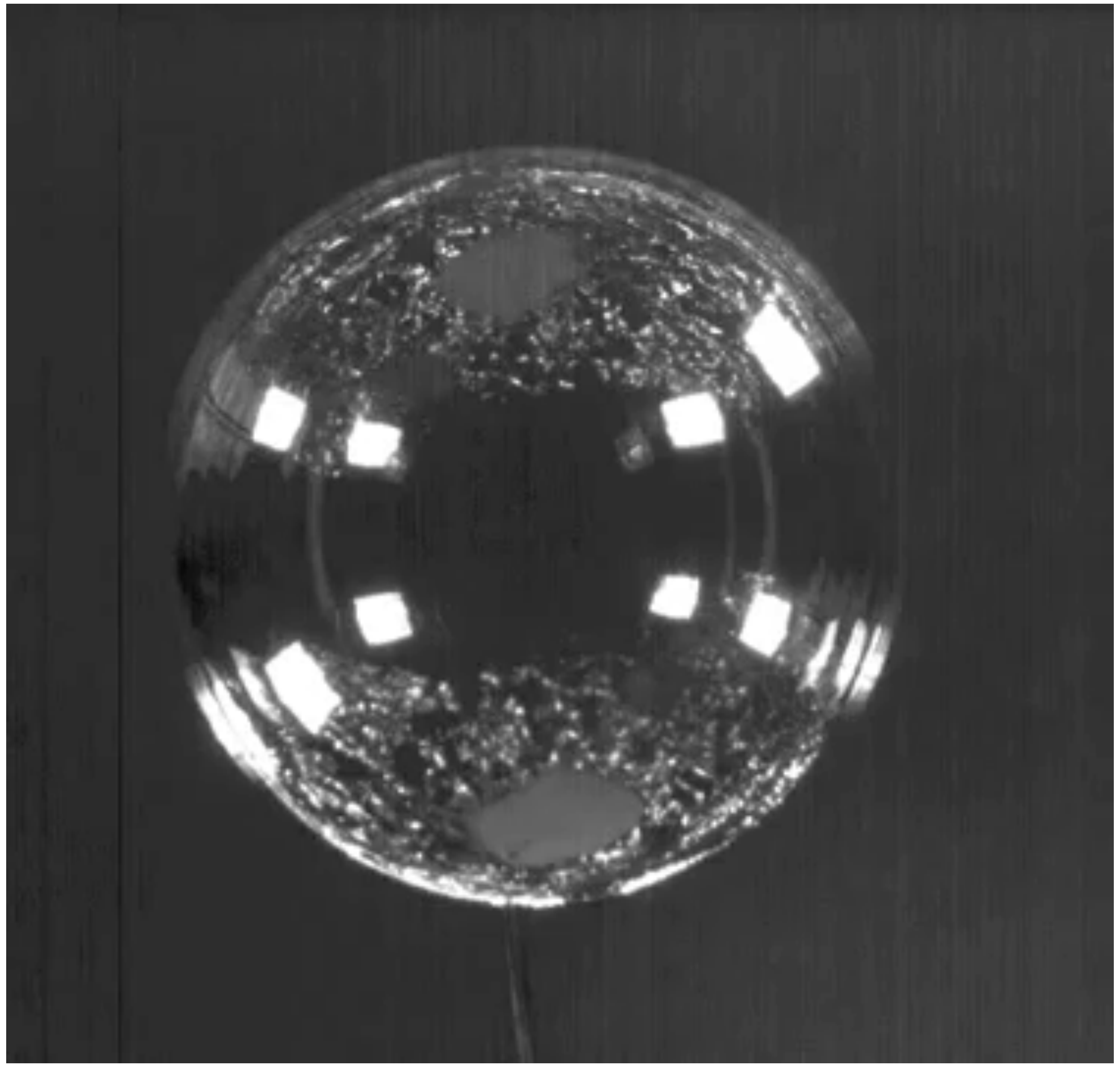


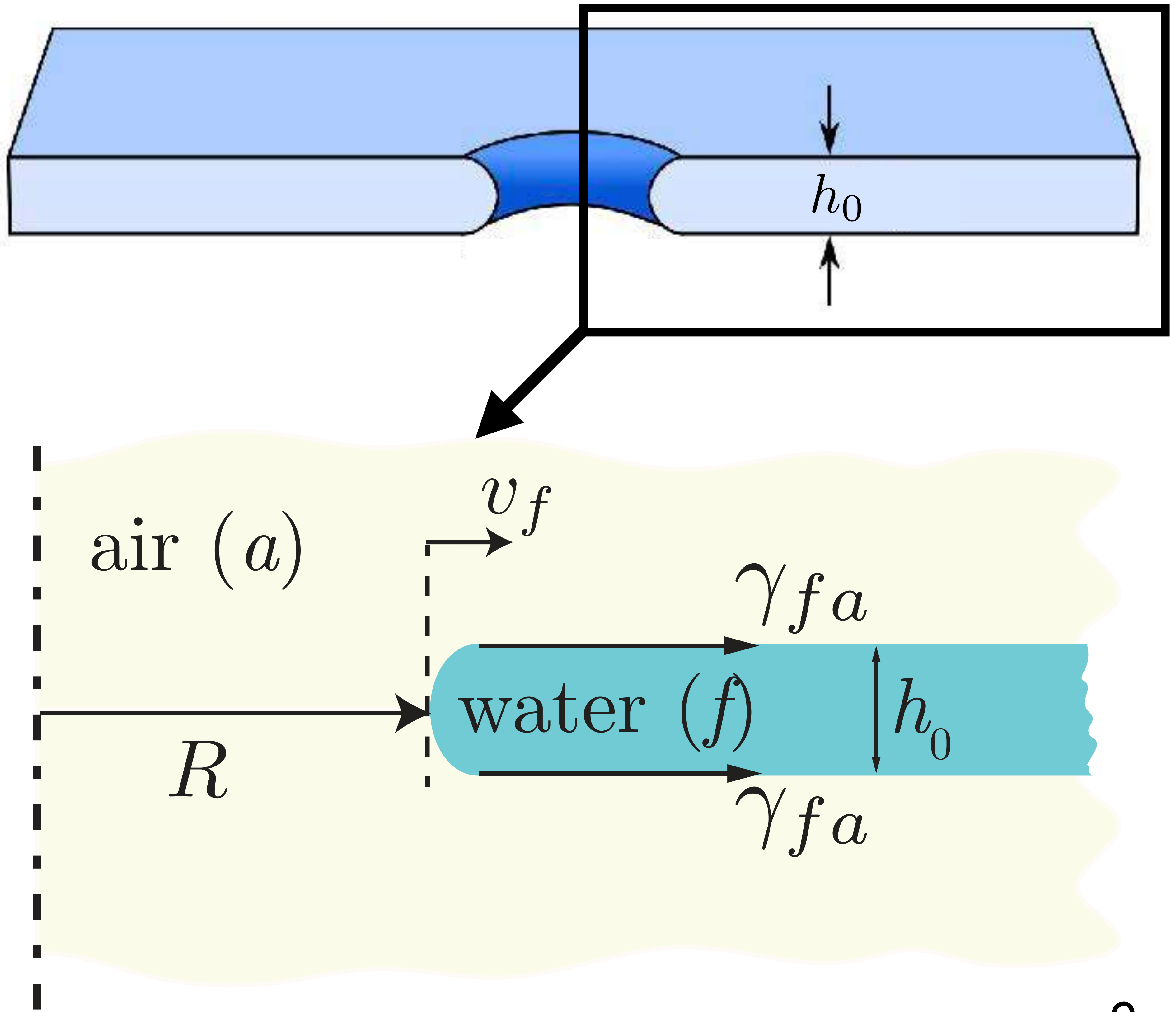
Bursting Soap Bubble



Video from https://fyfluiddynamics.com/2011/10/high-speed-video-of-a-soap-bubble-being-popped/

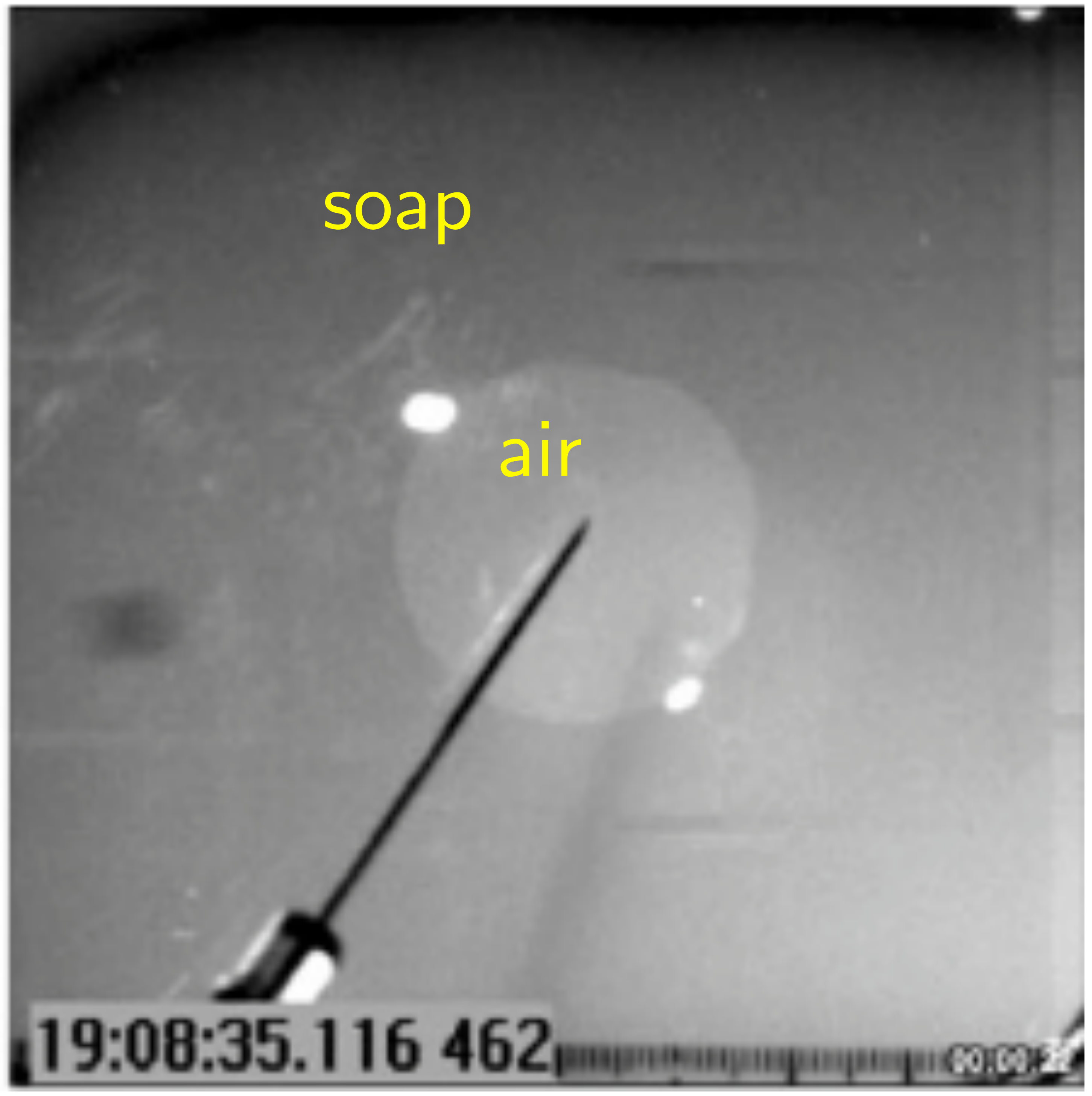
Bursting Soap Bubble





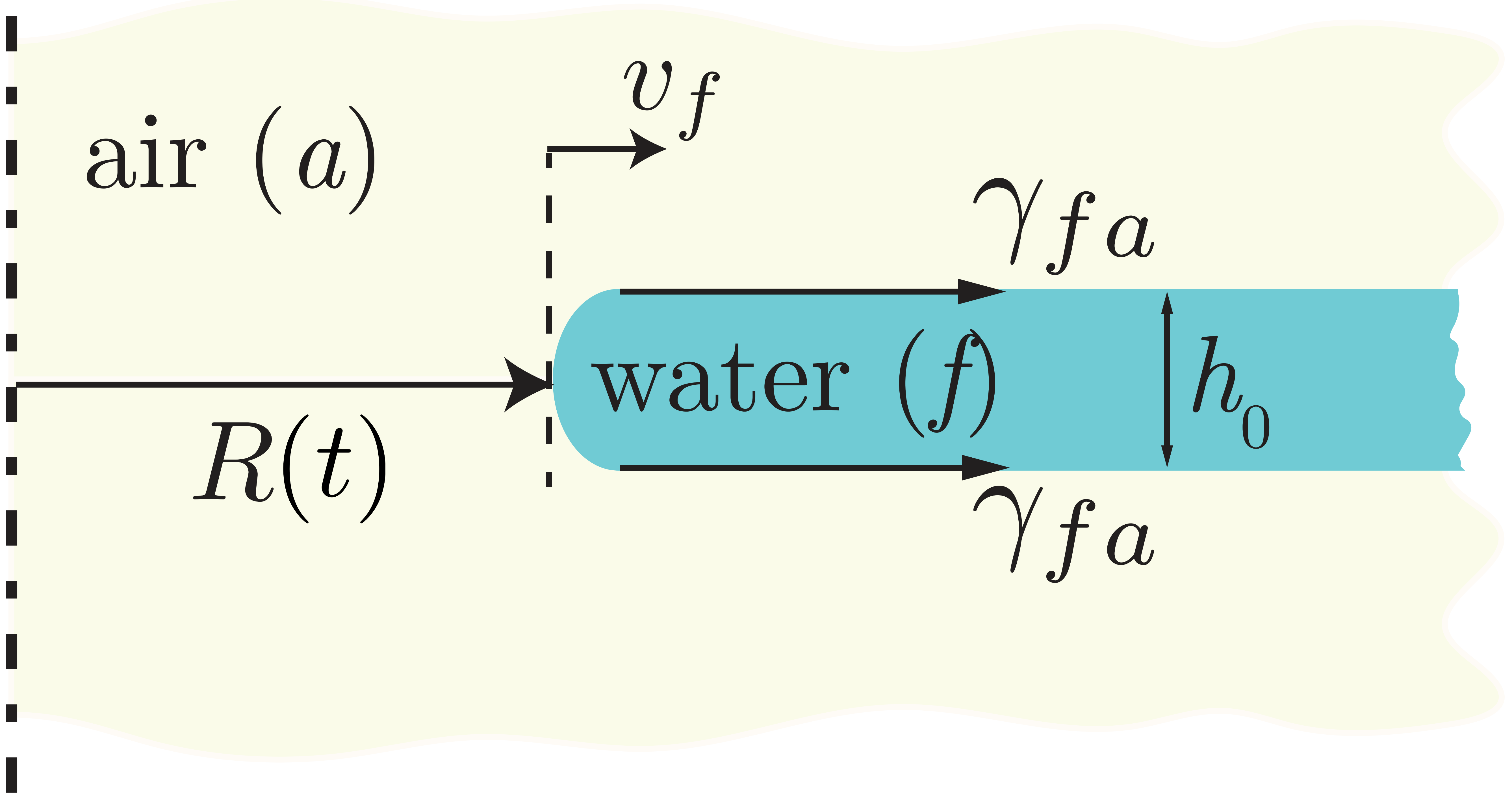
Classical Taylor–Culick retraction

$$Oh_f = \frac{\eta_f}{\sqrt{\rho_f\,(2\gamma_{fa})\,h_0}}$$



Savva & Bush,
J. Fluid Mech. 626, 211-240 (2009)

Top View



Side View

Dupré's & Rayleigh's calculations

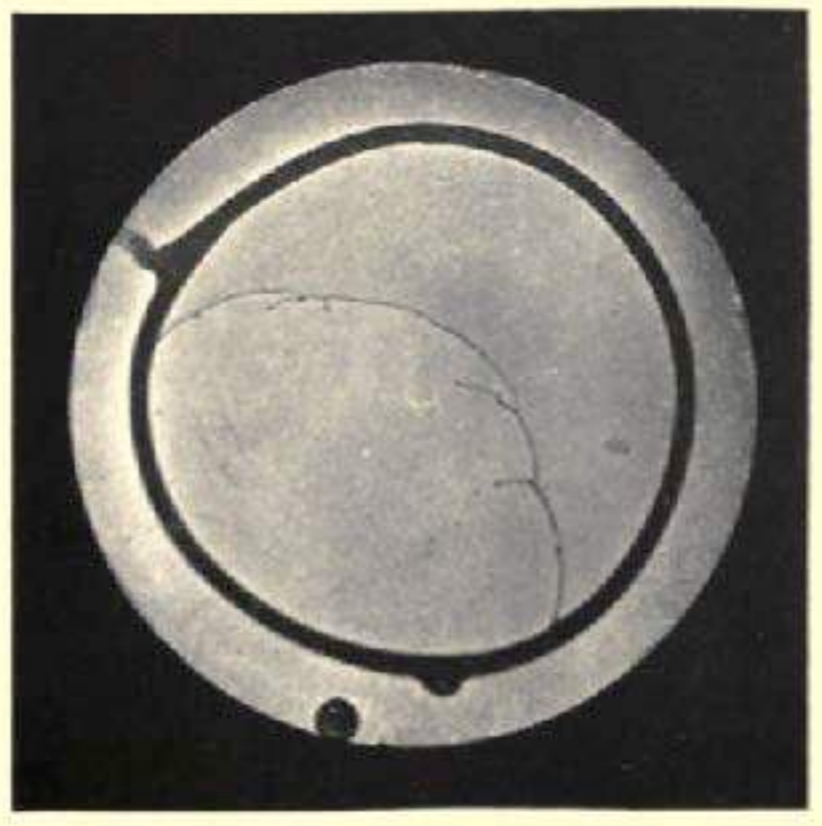
179.

SOME APPLICATIONS OF PHOTOGRAPHY.

[Proc. Roy. Inst. XIII. pp. 261—272, Feb. 1891; Nature, XLIV. pp. 249—254, 1891.]

Rayleigh, 1891

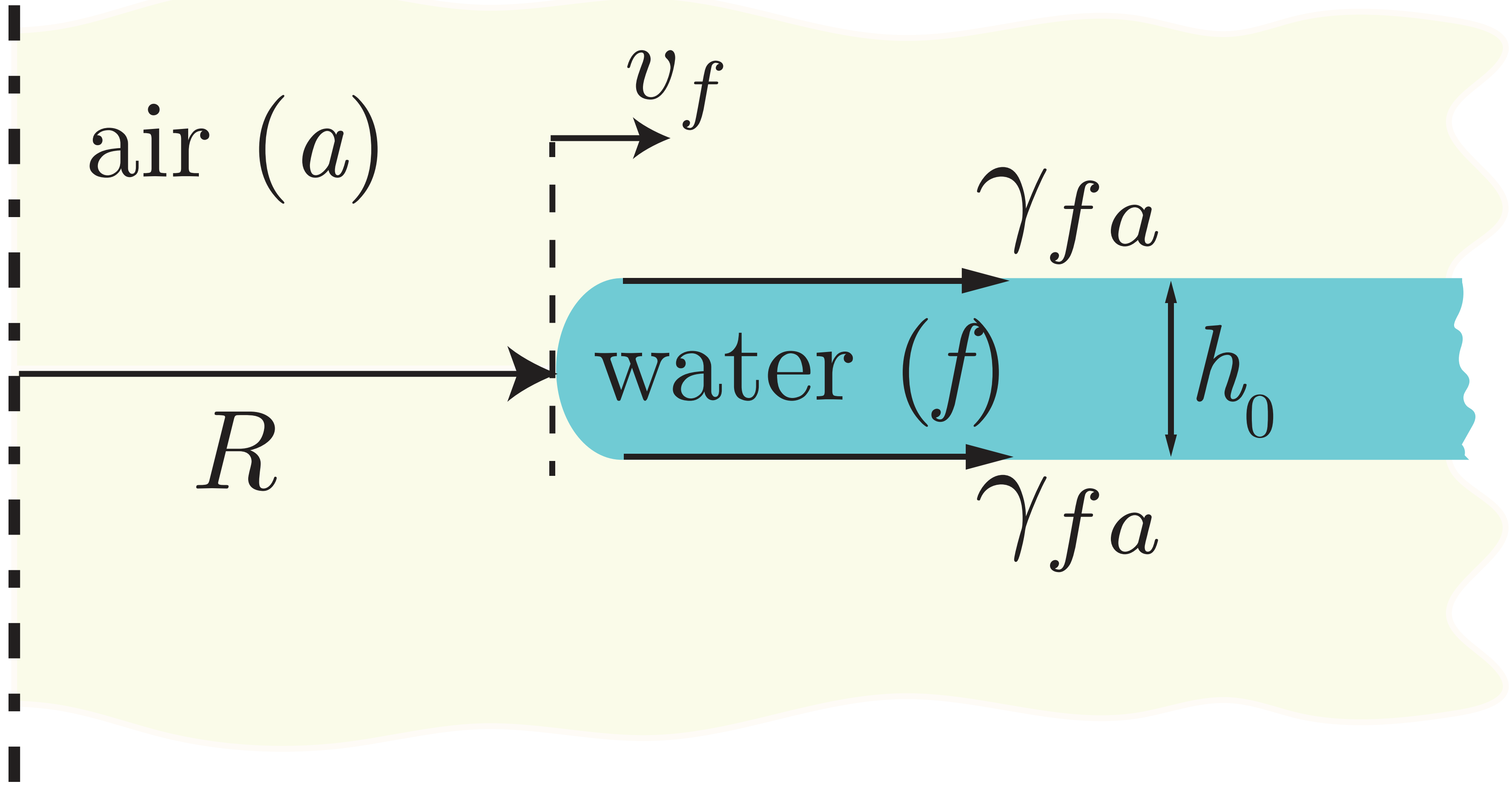
Fig. 7.



Prof. Dewar has directed my attention to the fact that Dupré, a good many years ago, calculated the speed of rupture of a film. We know that the energy of the film is in proportion to its area. When a film is partially broken, some of the area is gone, and the corresponding potential energy is expended in generating the velocity of the thickened edge, which bounds the still unbroken portion. The speed, then, at which the edge will go depends upon the thickness of the film. Dupré took a rather extreme case, and calculated a velocity of 32 metres per second. Here, with a greater thickness, our velocity was, perhaps, 16 yards [say 15 m.] a second, agreeing fairly well with Dupré's theory.

Rate of change in Surface energy —>

Rate of change of kinetic energy

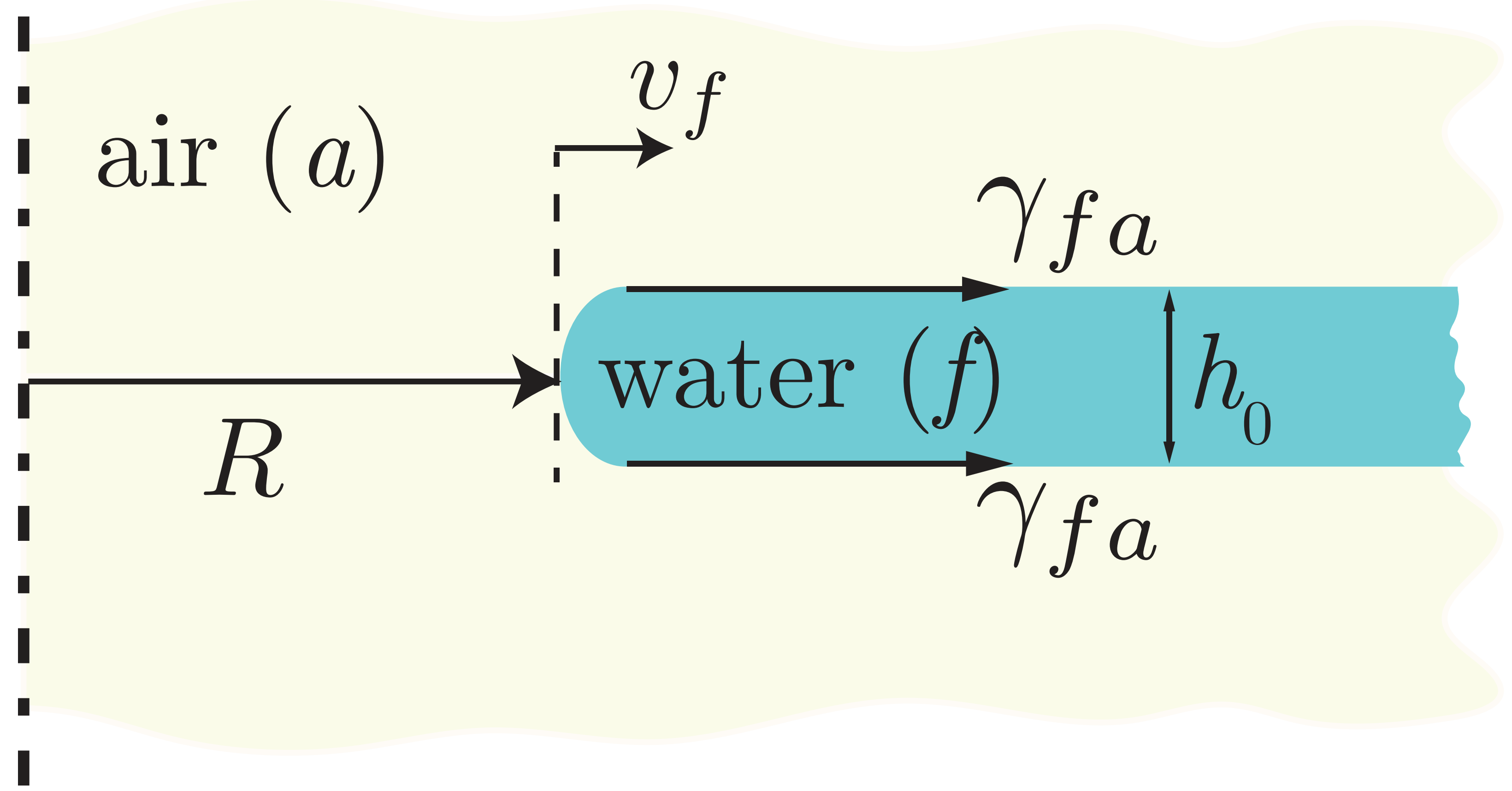


$$\frac{d}{dt}\left(\frac{1}{2}mv^2\right) = 2\gamma_{fa}\left(2\pi R\right)v$$

$$\frac{1}{2}\frac{dm}{dt}v^2 = 2\gamma_{fa}\left(2\pi R\right)v$$

Dupré–Rayleigh **paradox**

Rate of change in Surface energy —>
Rate of change of kinetic energy



$$\frac{d}{dt}\left(\frac{1}{2}mv^2\right) = 2\gamma_{fa}\,(2\pi R)\,v$$

$$\frac{1}{2}\frac{dm}{dt}v^2 = 2\gamma_{fa}\,(2\pi R)\,v$$

$$\frac{dm}{dt} = \rho v h(2\pi R)$$

$$v = \sqrt{\frac{4\gamma_{fa}}{\rho h_0}}$$

This velocity did not agree with the experimental observations!

Momentum balance

Classical Taylor–Culick retraction

G. I. Taylor

Force perspective

$$\frac{dP}{dt} = 2\gamma_{fa}\,(2\pi R) \qquad \frac{d}{dt}\,(mv_f) = 2\gamma_{fa}\,(2\pi R)$$

$$\frac{d}{dt}\,(mv_f) = v_f\,\frac{dm}{dt} = \rho v_f^2 h_0 (2\pi R)$$

$$v_f = \sqrt{\frac{2\gamma_{fa}}{\rho h_0}}$$

THE DYNAMICS OF THIN SHEETS OF FLUID
III. DISINTEGRATION OF FLUID SHEETS

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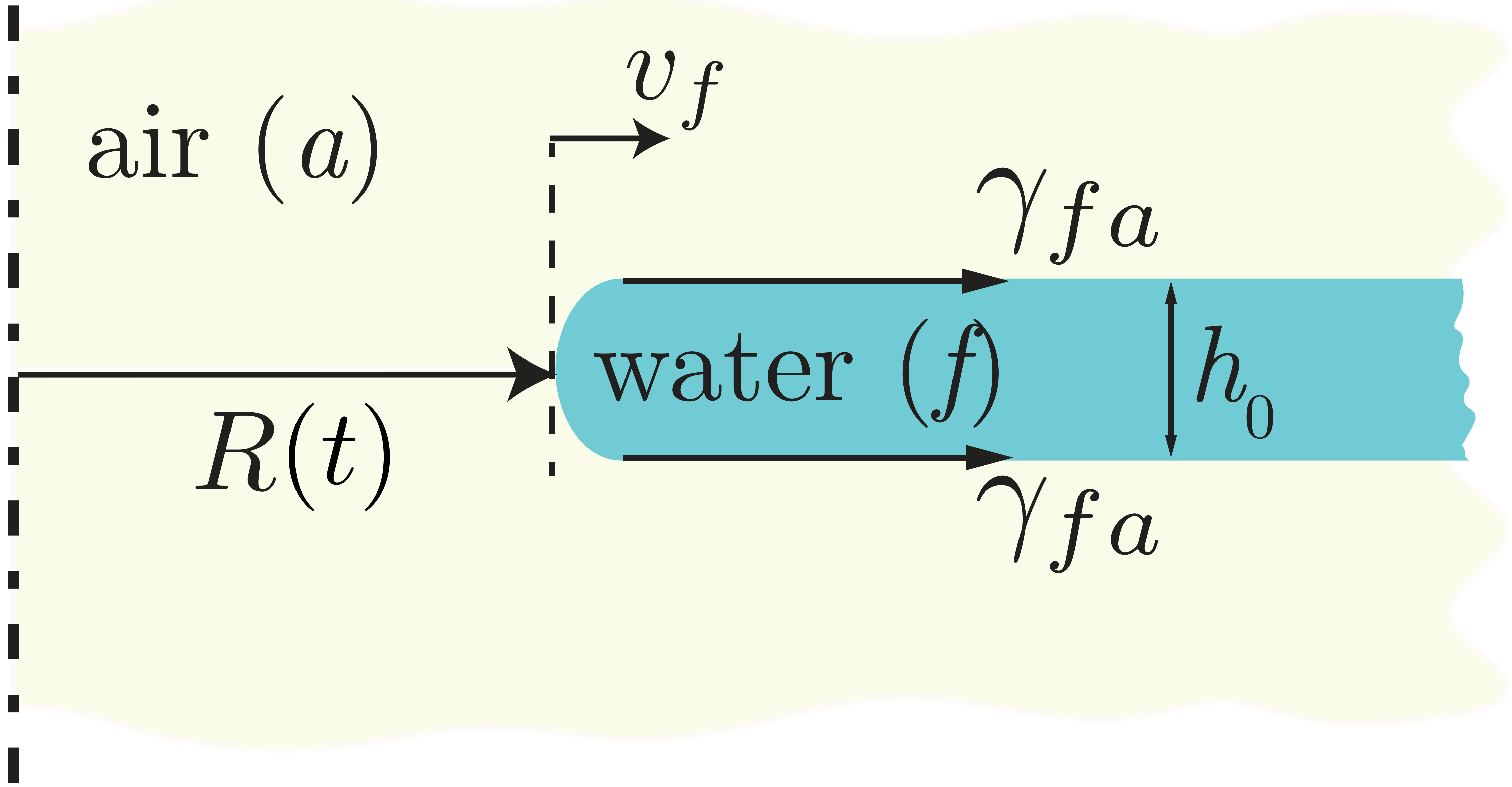
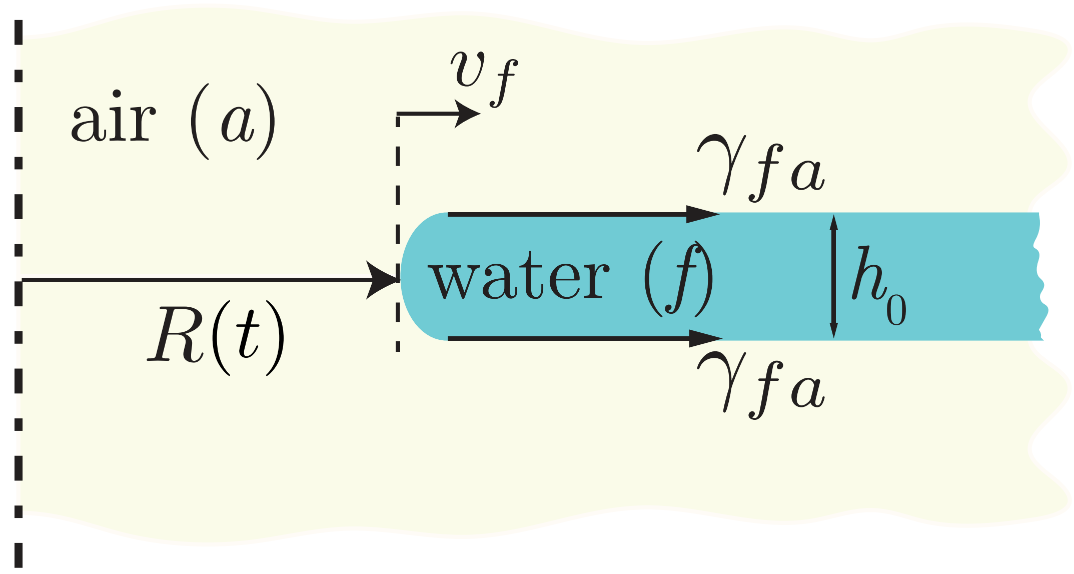


Retraction velocity???

G. I. Taylor



Force perspective

$$v_f = \sqrt{\frac{2\gamma_{fa}}{\rho h_0}}$$

Energy perspective

$$v_f = \sqrt{\frac{4\gamma_{fa}}{\rho h_0}}$$

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[*Proc. Roy. Inst.* XIII. pp. 261—272, Feb. 1891; *Nature*, XLIV. pp. 249—254, 1891.]

What went wrong?

Classical Taylor–Culick retraction

$$Oh_f = 0.05$$

$$Oh = \frac{\eta}{\sqrt{\rho_f (2\gamma_{af}) h_0}}$$

$$t/\tau_\gamma = 42.900$$

0 1

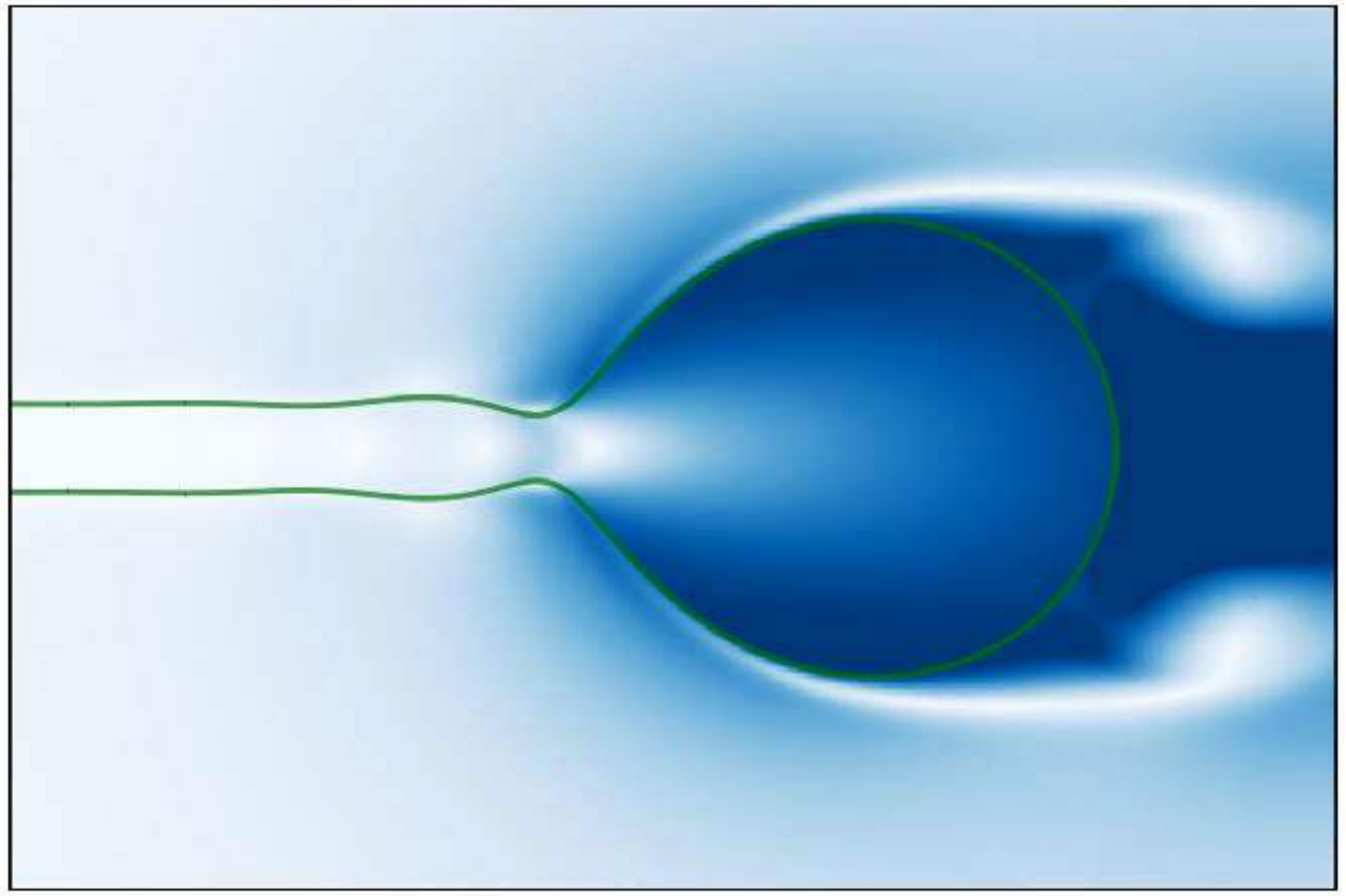
$\|\boldsymbol{v}\|/v_\gamma$

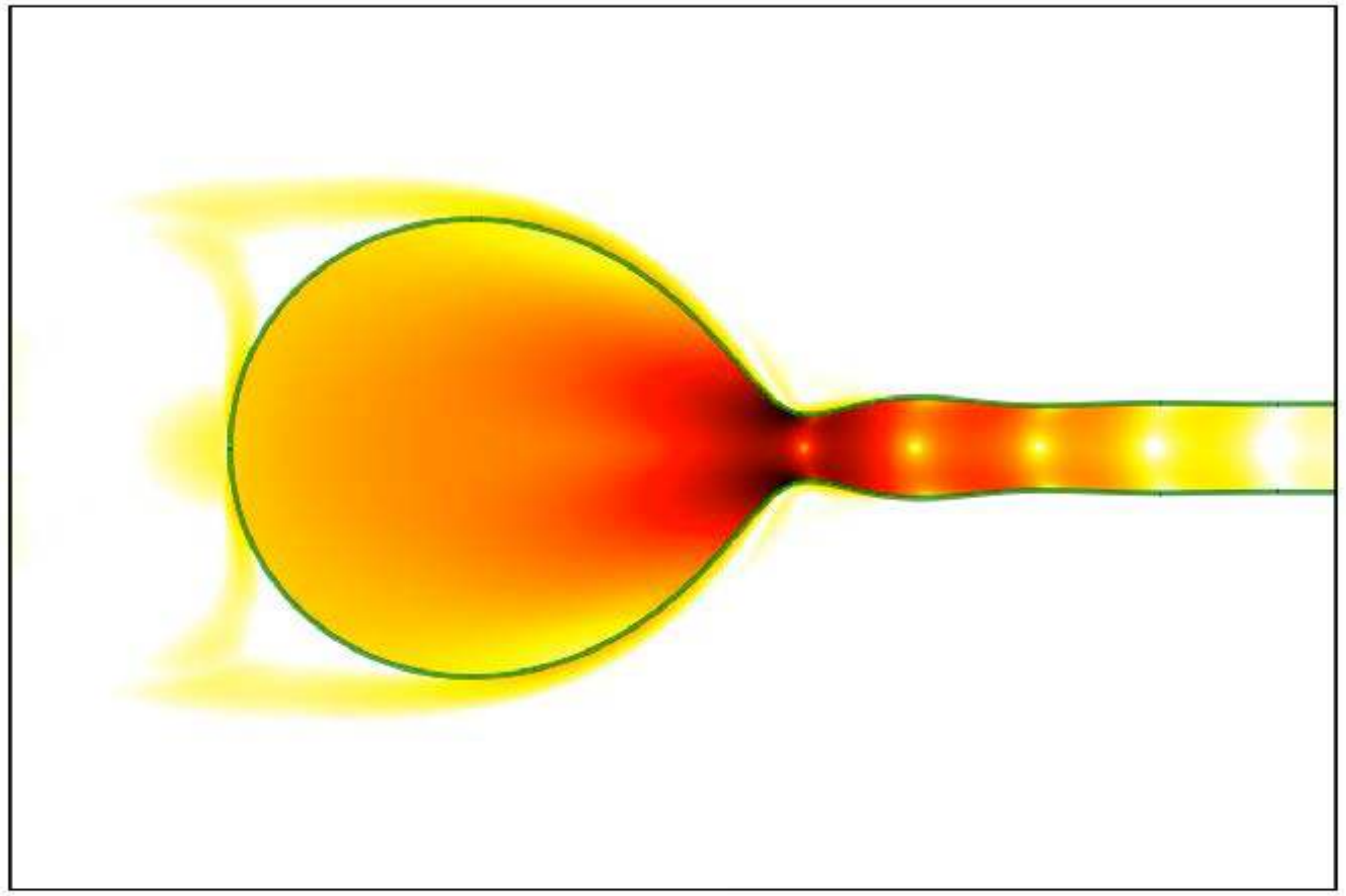
-5 0

$\log_{10}\left(2Oh\left(\boldsymbol{\mathcal{D}}:\boldsymbol{\mathcal{D}}\right)\tau_\gamma^2\right)$

$$\boldsymbol{\mathcal{D}} = \left(\boldsymbol{\nabla v} + \left(\boldsymbol{\nabla v}\right)^{\mathrm{T}}\right)/2$$

$$\tau_\gamma = \sqrt{\frac{\rho_f h_0^3}{2\gamma_{af}}} \quad v_\gamma = \sqrt{\frac{2\gamma_{af}}{\rho_f h_0}}$$





How to calculate the viscous dissipation?

Faraday Discuss., 1996, **104**, 1–8

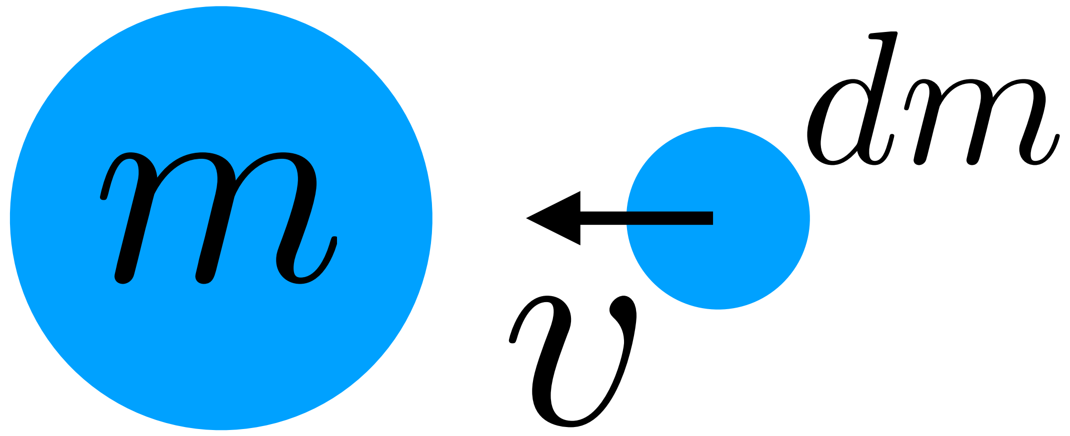
Introductory Lecture

Mechanics of soft interfaces

Pierre-Gilles de Gennes
Laboratoire de Physique de la Matière Condensée, Collège de France, 11, place Marcelin-Berthelot, 75231 Paris Cedex 05, France

P.-G. de Gennes

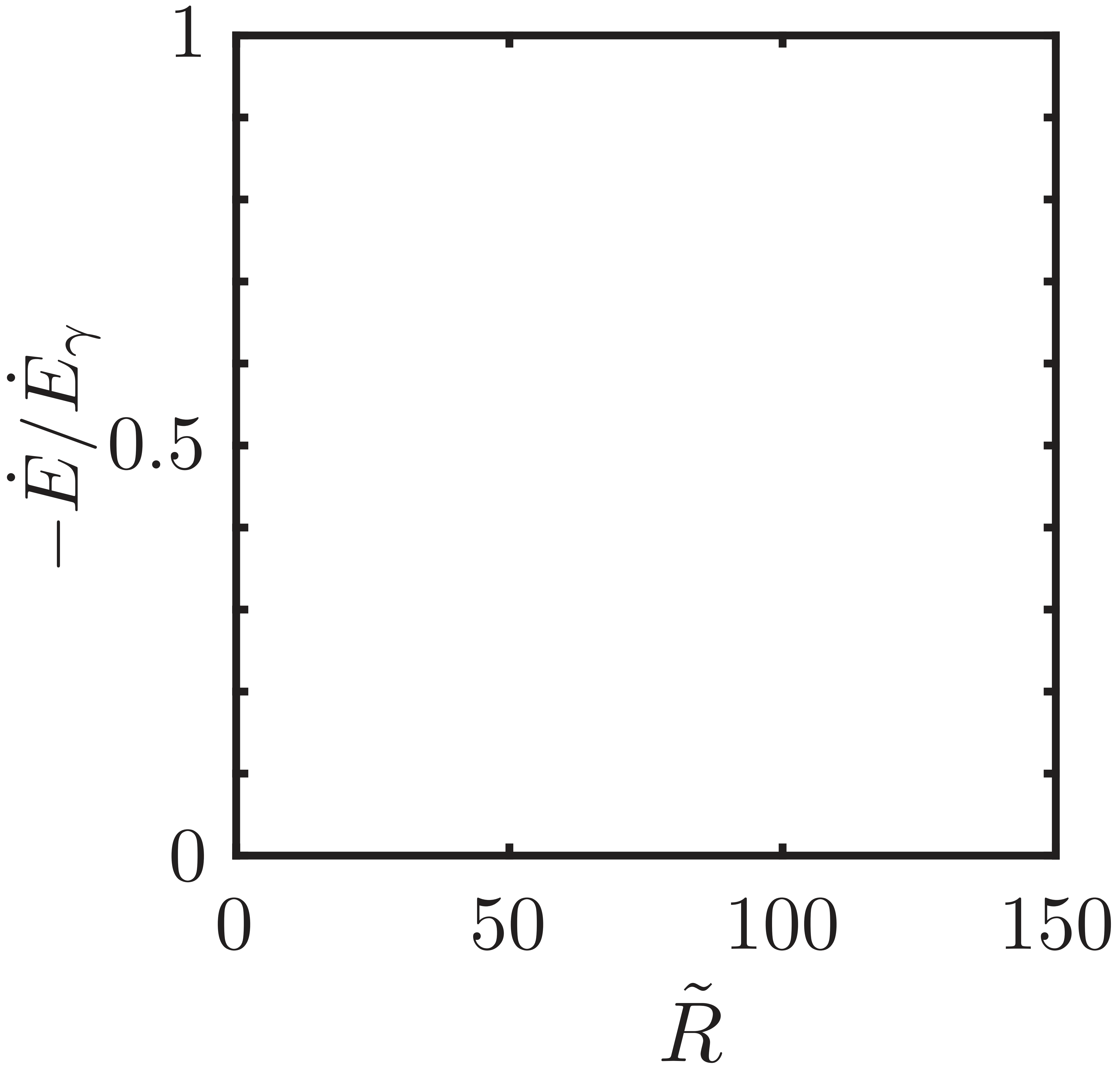
Energy lost due to plastic collision

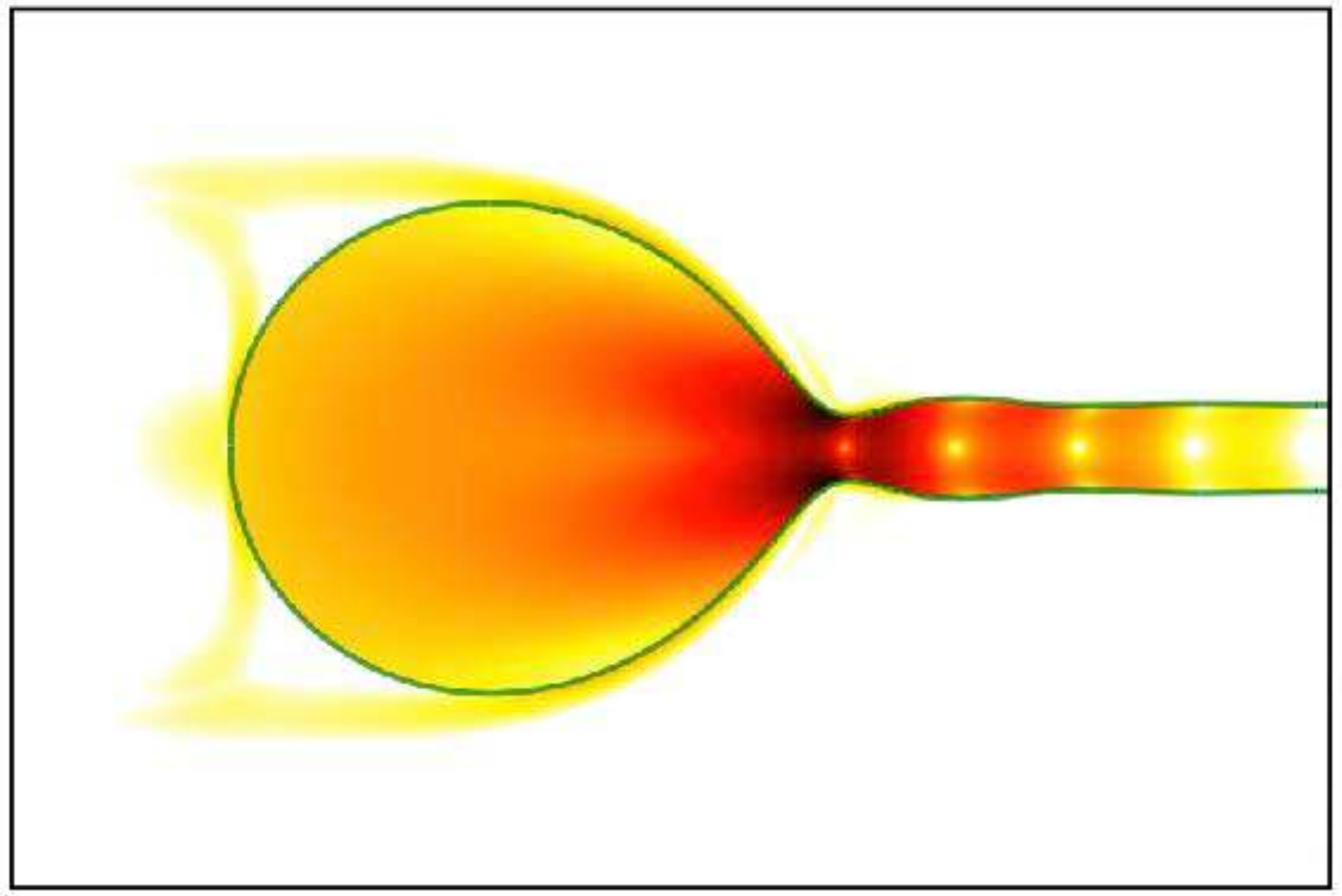


In frame of reference of the rim

$$\dot{E}_d = \frac{1}{2}\frac{dm}{dt}v^2$$

Energy Budget: Classical Taylor-Culick retraction





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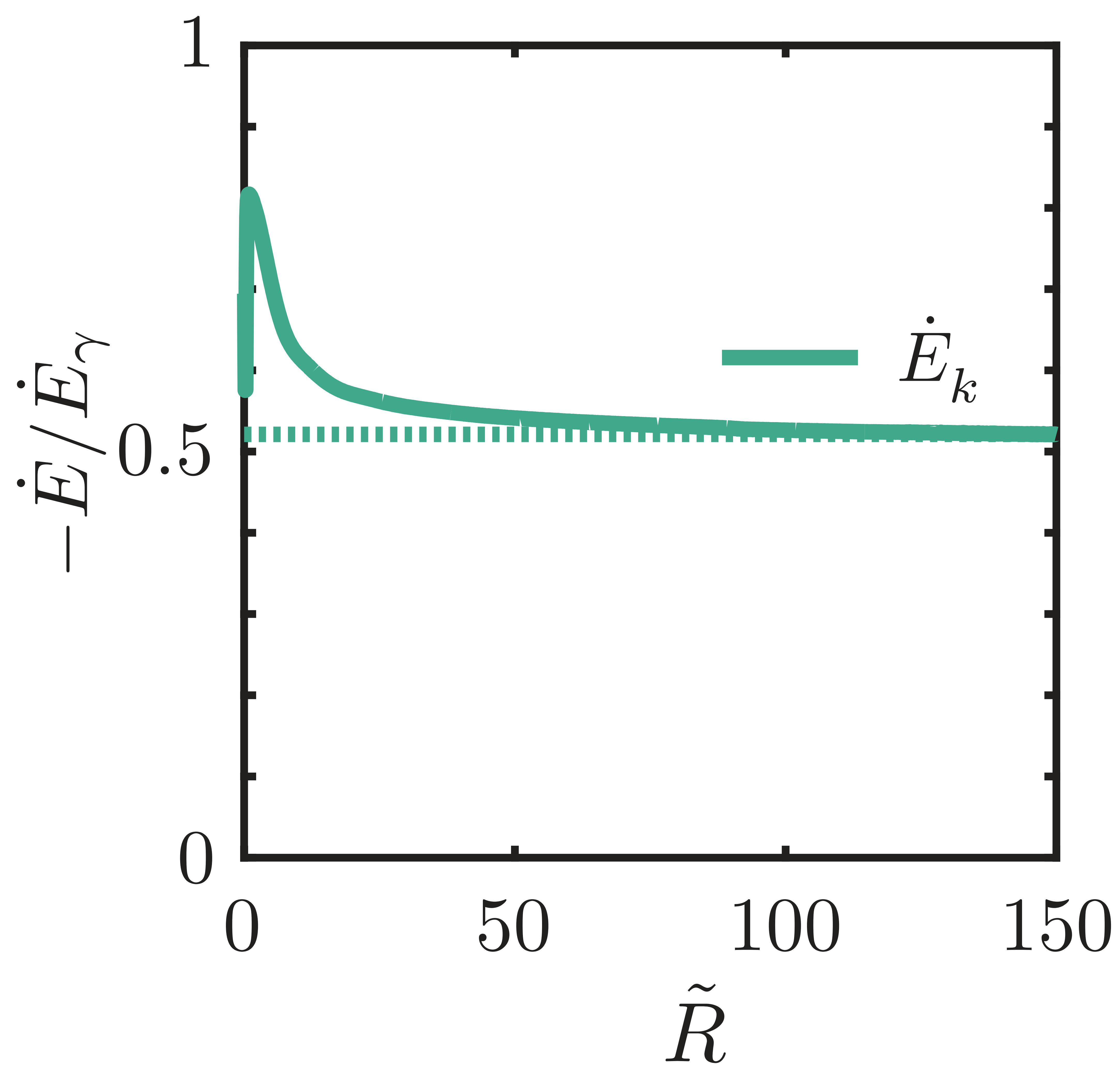
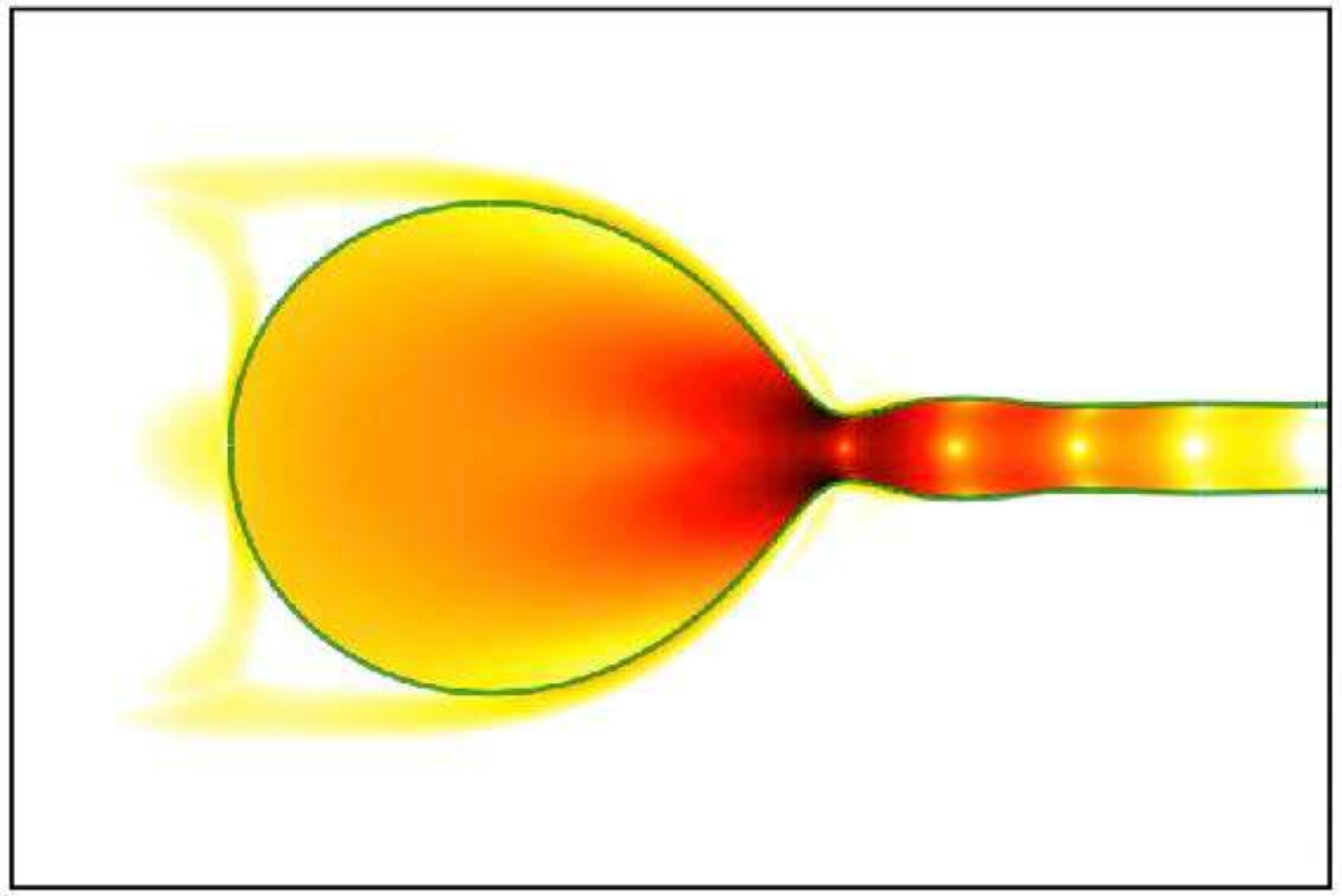
F. E. C. Culick

P.-G. de Gennes

Energy Budget: Classical Taylor-Culick retraction





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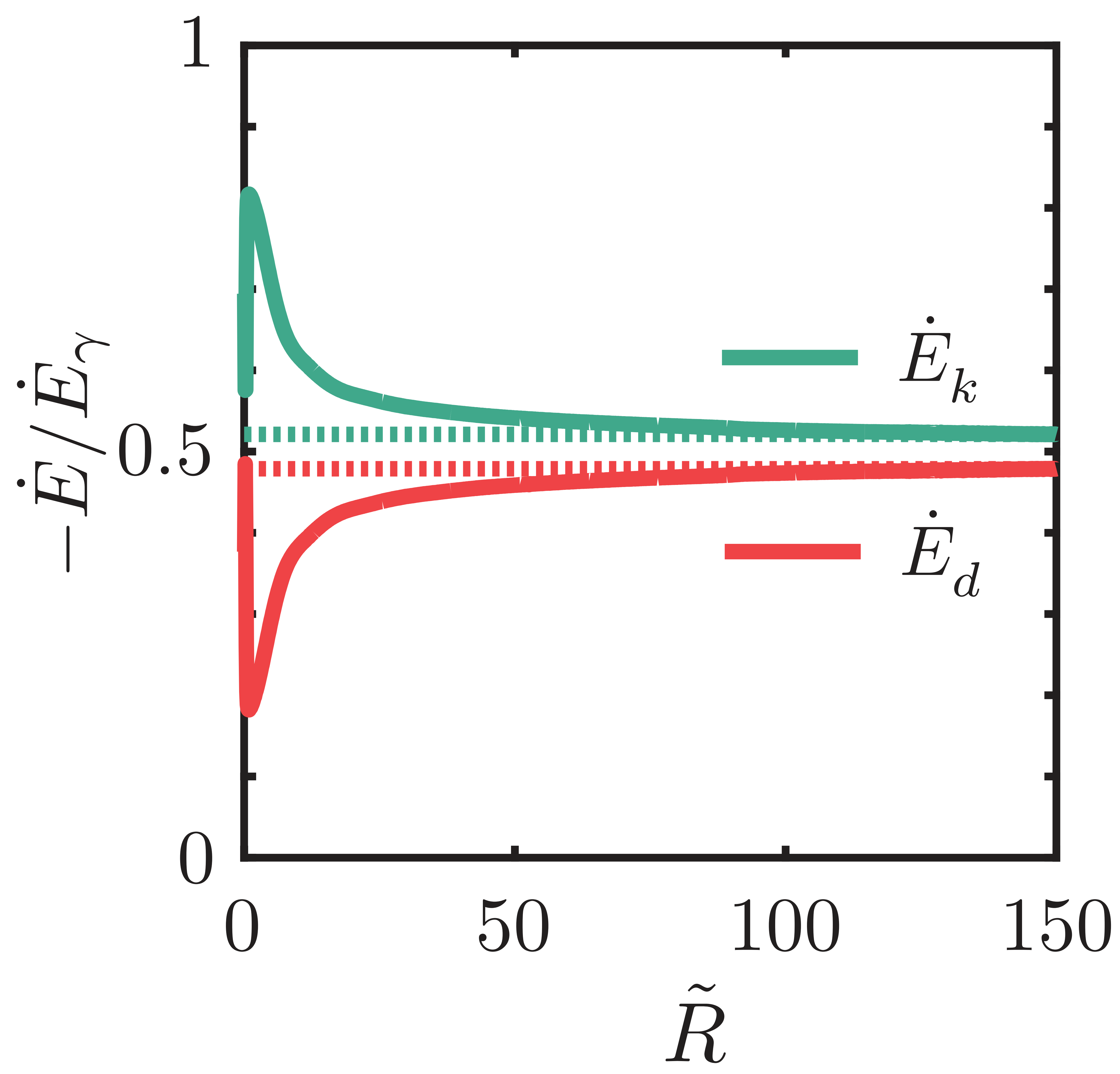
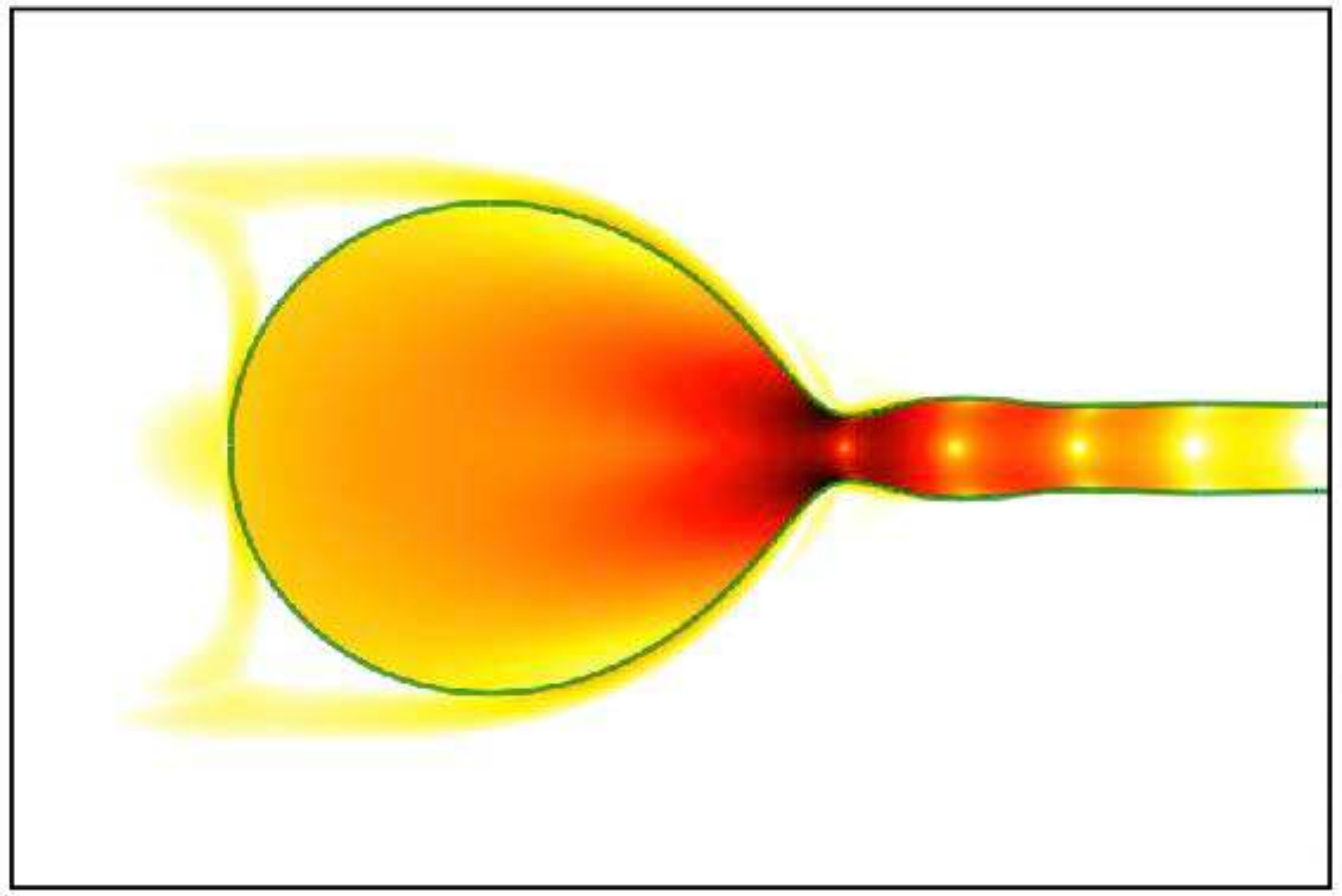
Energy Budget: Classical Taylor-Culick retraction





$$-\Delta \dot{E}_\gamma(t) \approx \dot{E}_k(t)^f + \dot{E}_d(t)^f$$

$$\dot{E}_d = \frac{1}{2}\frac{dm}{dt}v^2$$

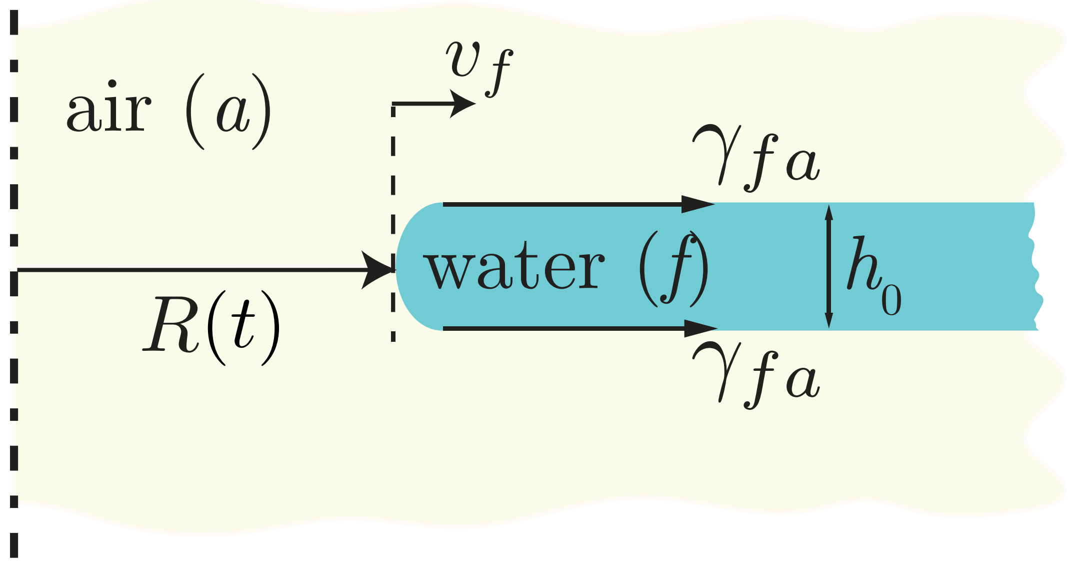

G. I. Taylor


F. E. C. Culick


P.-G. de Gennes

Classical Taylor-Culick retraction

G. I. Taylor



F. E. C. Culick

Force perspective

$$\frac{dP}{dt} = 2\gamma_{fa}\,(2\pi R) \qquad \frac{d}{dt}\left(m v_f\right) = 2\gamma_{fa}\,(2\pi R)$$

$$\frac{d}{dt}\left(m v_f\right) = v_f \frac{dm}{dt} = \rho v_f^2 h_0 (2\pi R)$$

$$v_f = \sqrt{\frac{2\gamma_{fa}}{\rho h_0}}$$

Energy perspective

$$F\frac{dR}{dt} = 2\gamma_{fa}\,(2\pi R)\,v_f$$

$$= \frac{d}{dt}\left(\frac{1}{2} m v_f^2\right) + \frac{1}{2}\frac{dm}{dt} v_f^2$$

$$v_f = \sqrt{\frac{2\gamma_{fa}}{\rho h_0}}$$

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Comments on a Ruptured Soap Film

Cite as: Journal of Applied Physics **31**, 1128 (1960); https://doi.org/10.1063/1.1735765
Submitted: 05 January 1960 . Published Online: 16 June 2004

F. E. C. Culick

Synopsis of Classical Taylor-Culick retractions

$$v_f = v_{TC} = \sqrt{\frac{(2\gamma_{fa})}{\rho_f h_0}}$$

- Even in the inertial limit, cannot neglect viscous dissipation in the thin film (singular for $Oh \to 0$)

$$-\Delta\dot{E}_\gamma(t) \approx \dot{E}_k(t)^f + \dot{E}_d(t)^f$$

- Dissipation is independent of viscosity.

$$\dot{E}_d = \frac{1}{2}\frac{dm}{dt}v^2$$