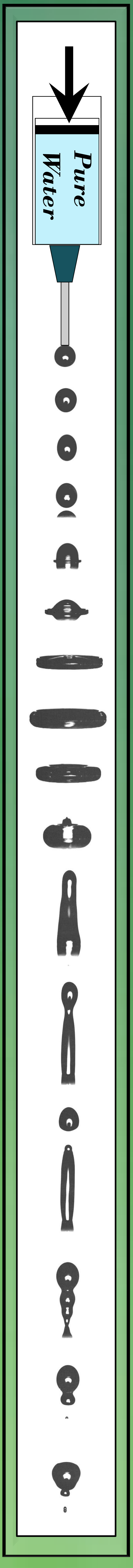
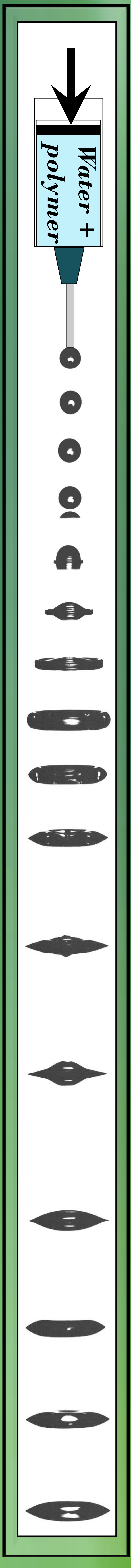
Making Droplets Stick

Understanding the anti-rebound effect of dilute polymer solutions

Michael Smith[1] & Volfango Bertola[2]

1. School of Physics & Astronomy, University of Nottingham, Nottingham, NG7 2RD
2. SMART Laboratory, University of Edinburgh, Edinburgh, EH9 3JL

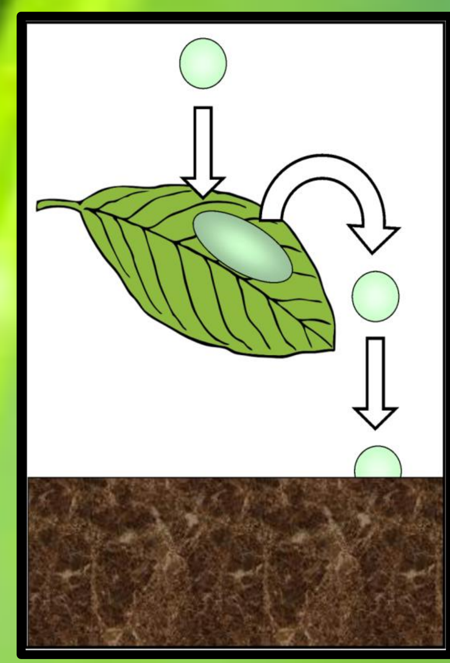




Controlling droplet impact

When a droplet of water impacts a hydrophobic surface such as the waxy leaf of a plant it rebounds. Controlling droplet impact limits waste of ecologically damaging and expensive pesticides or fertilizers.

Droplet impact is an important factor in many industrial applications: inkjet printing, spray cooling, internal combustion engines.

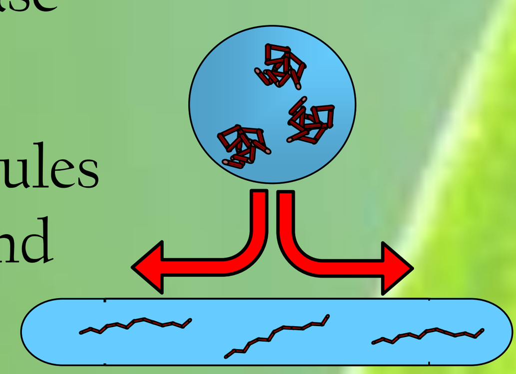


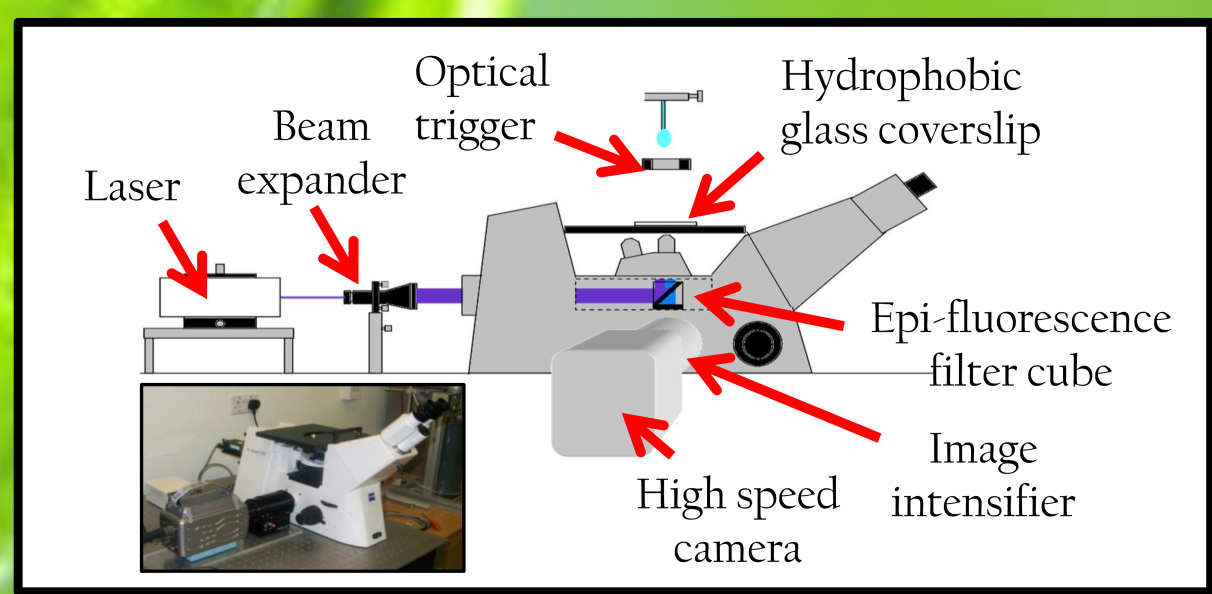
The anti-rebound effect

Adding small quantities of a flexible polymer (~100μgml^{-1}) to droplets of water completely prevents rebound (see figures to left) . This is highly surprising since the surface tension and viscosity of dilute polymer solutions are very similar to those of pure water.

Since its discovery, the anti-rebound phenomenon has been attributed to a temporary increase in the "extensional" viscosity.

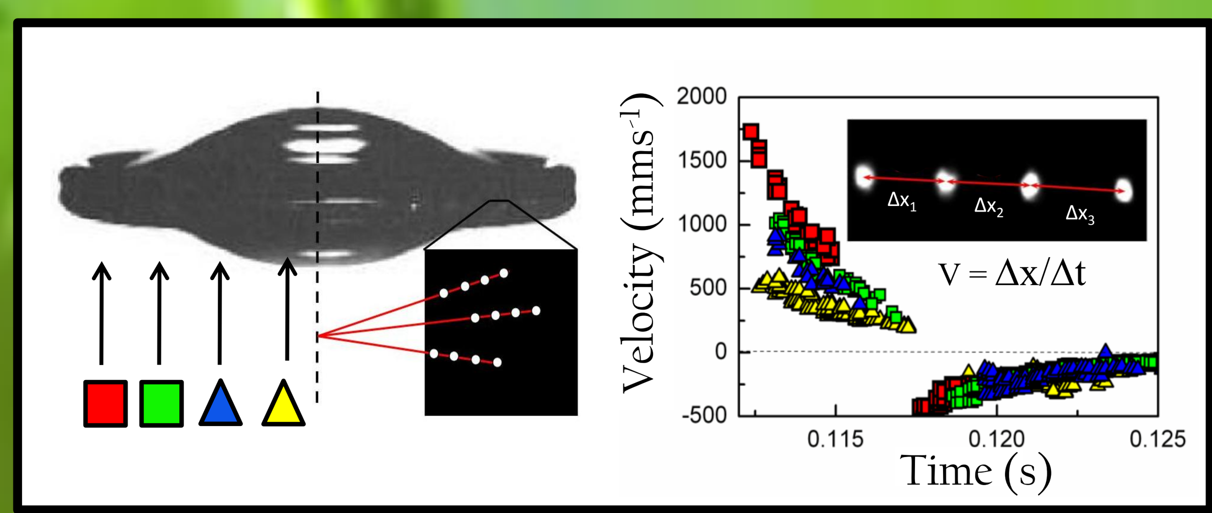
It was suggested that polymer molecules stretch in the flow of the spreading and retracting droplet leading to viscous dissipation → No rebound.





Is extensional viscosity responsible for the anti-rebound effect?

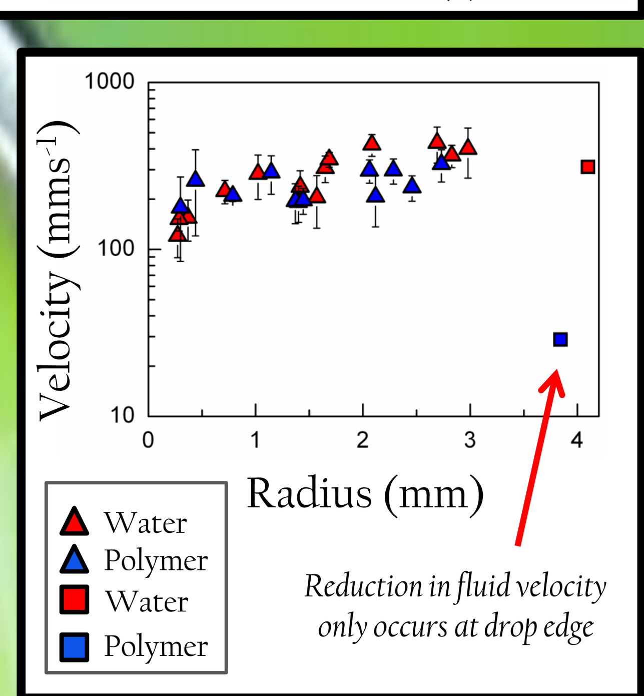
A high speed fluorescent microscopy set up capable of imaging the interior of an impacting drop at 2000 fps was constructed.



Fluorescent tracer particles were used to measure the fluid velocity at different positions inside the droplet with time. Each particle was exposed 4x in each frame using a pulsed laser.

Fluid retraction velocity depends on viscosity. Drops with & without polymer show similar bulk fluid velocities (figure to right). This means the extensional viscosity is similar so **cannot** be responsible for the anti-rebound effect.

Velocity reduction only occurs near the drop edge. **The anti-rebound effect must therefore be a drop edge effect.**



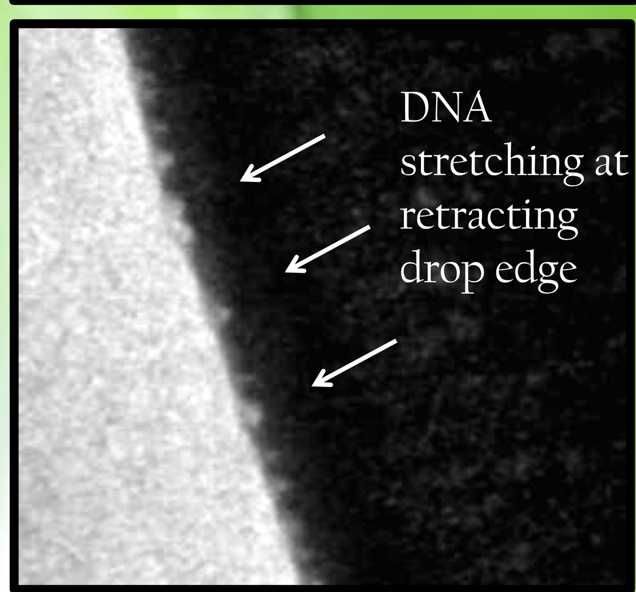
Visualising polymers at the drop edge

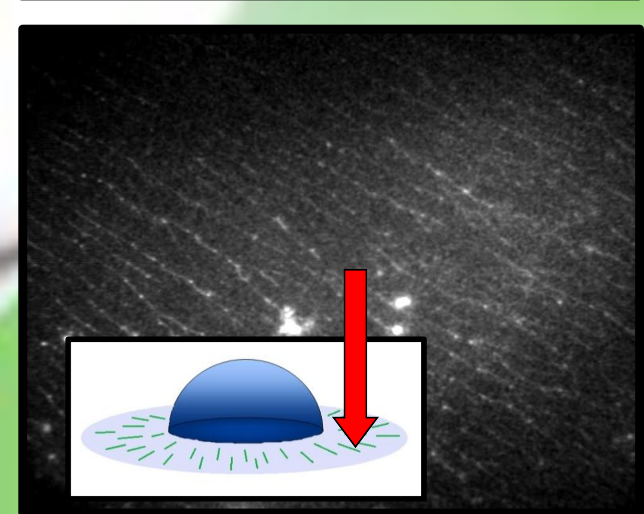
To study the dynamics of polymers at the moving drop edge, a fluorescently labelled biopolymer (λ-DNA) was used.

DNA molecules are stretched at the retreating drop edge, resulting in a "stick-slip" motion. Stretching of polymers at the edge of the drop dissipates energy.

→ No rebound

DNA is left behind stretched out radially on the surface.





Conclusions

The anti-rebound effect is <u>not</u> due to changes in the drop's extensional viscosity.

Polymers stretching at the drop edge dissipate energy preventing rebound.

[1] M.I. Smith, V. Bertola, *Phys. Rev. Letts* ***104***, 154502 (2010)

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