Head-on impact of liquid drops

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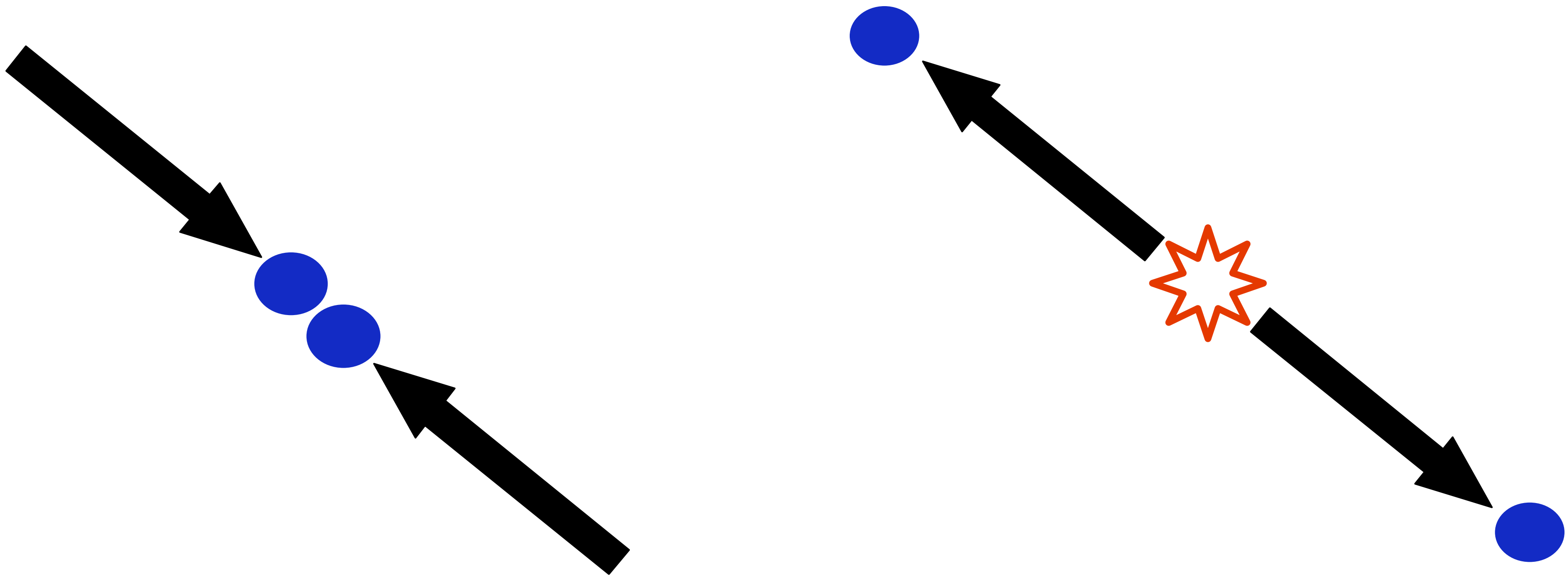
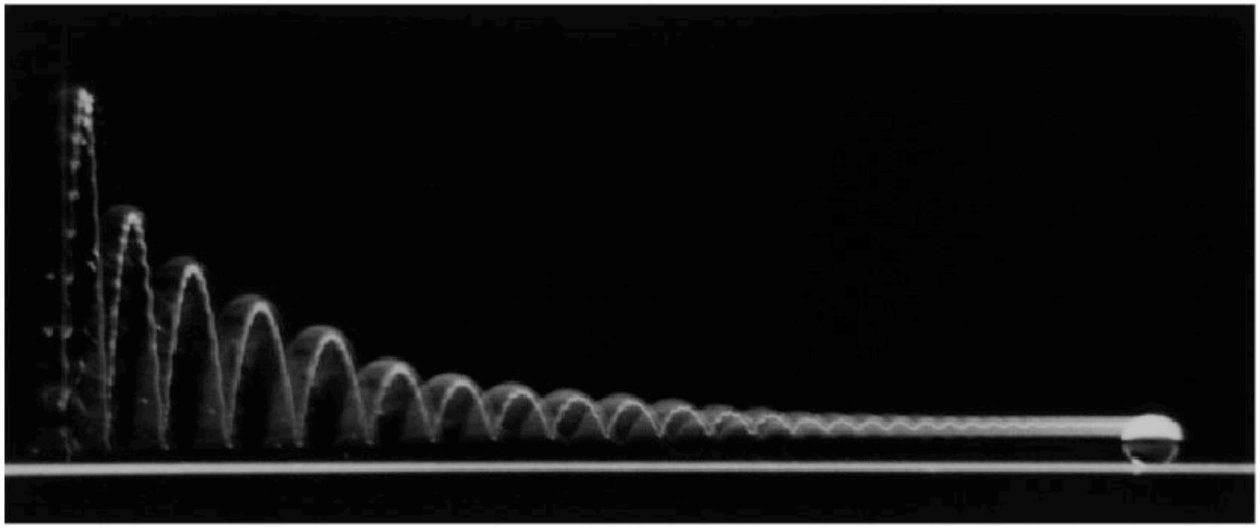
1. When 2 point particles collide
Outcome controlled by energy & momentum conservation
No dependence on details of interaction

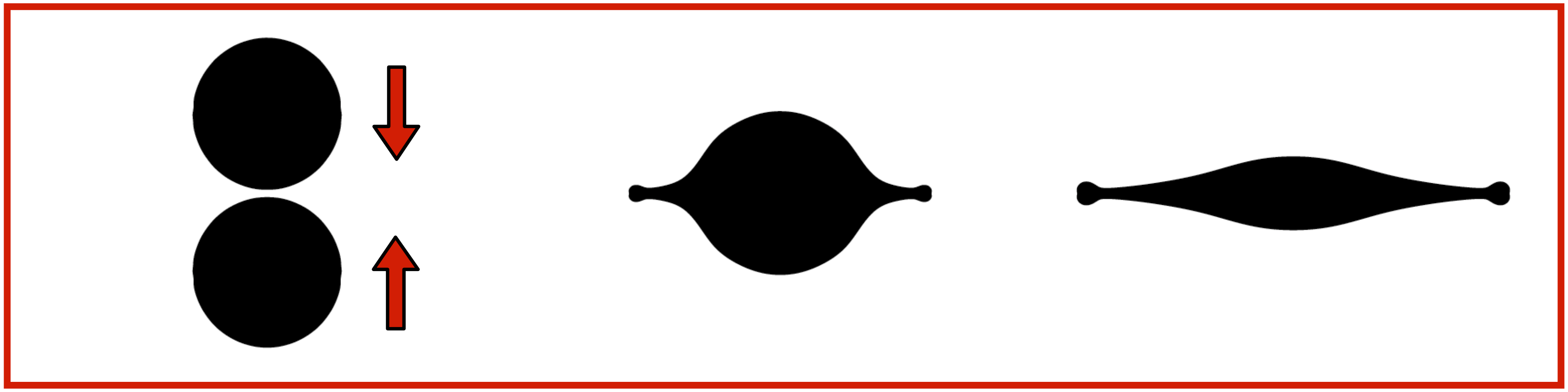


2. At low impact speed, liquid drop bounces like point particle



Richard and Quéré, Europhys. Lett. **50**, *769*

At high impact speed, thin sheet ejected by colliding drops



3. Relevant parameters (No air effects)

U_s surface deformation speed — *0.1 m/s*

*[surface tension / (drop size * density)]$^{1/2}$*

U_0 impact speed — *1 m/s*

C speed of sound — *1500 m/s*

$$U_s << U_0 << C$$

Spherical shape until contact with impact plane ← → *incompressible flow*

Deformation dominated by inertia

4. Simulating of Drop Impact

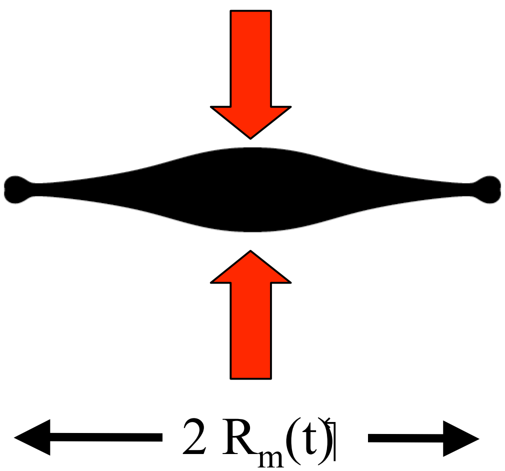
Axisymmetric volume-of-fluid code

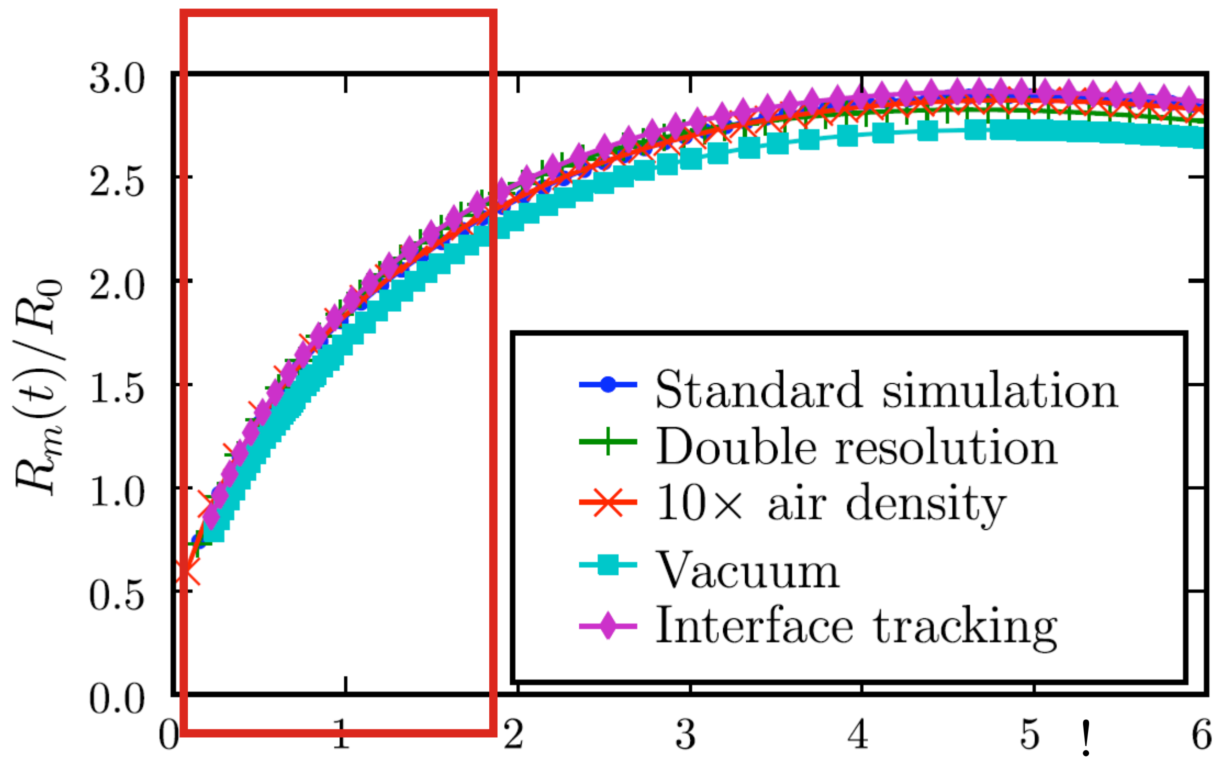
- Solves two-fluid incompressible Navier-Stokes equations

- Air effects negligble on evolution of top surface (P_g = 0.1 atm)

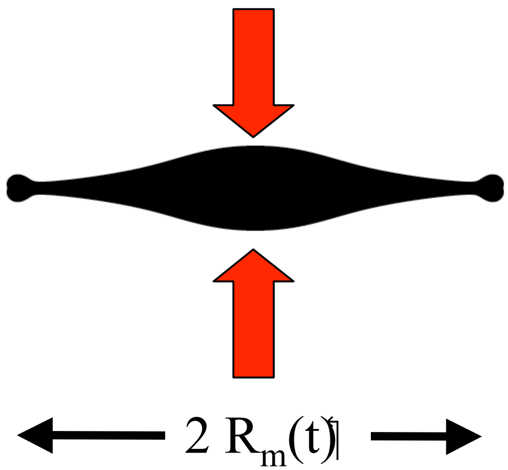
- Drop interface not broken at impact plane

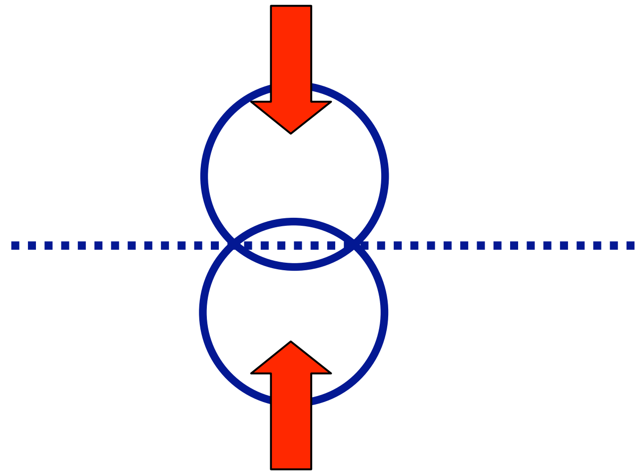
Laufaurie et al, *J. Comp. Phys.* ***113****, 134 (1994)!*





5. Rapid radial expansion at early times





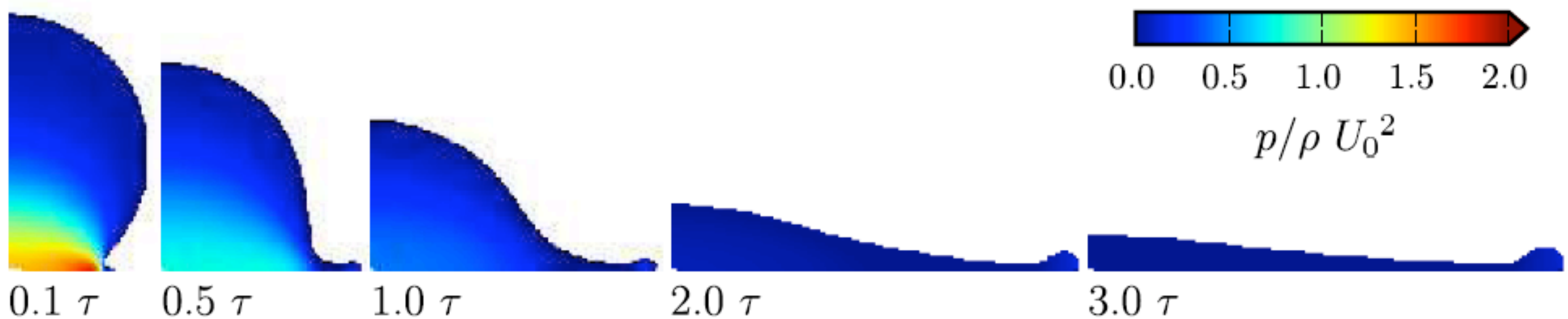
$R_m(t) \approx$ ***[4 (drop size) × (impact speed) × (time since impact)]***$^{1/2}$

$dR_m/dt \approx$ ***[(drop size) × (impact speed) / (time since impact)]***$^{1/2}$

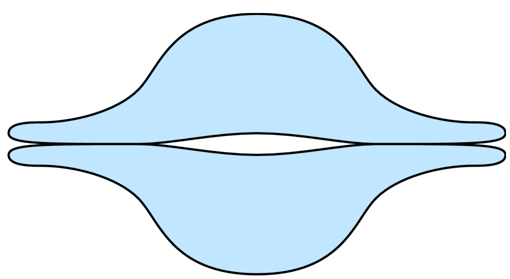
What cuts of the diverging expansion speed?

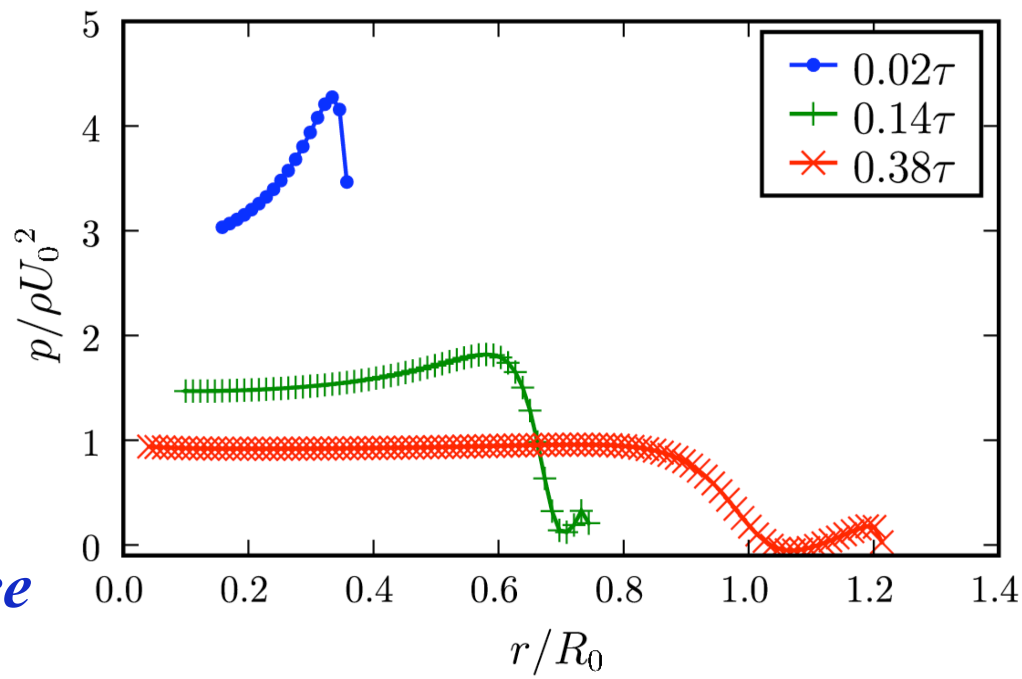
6. Simulation show ejection driven by inertia

volume conservation ➔ pressure variation ➔ liquid ejected radially



! = radius / impact speed
impact time-scale

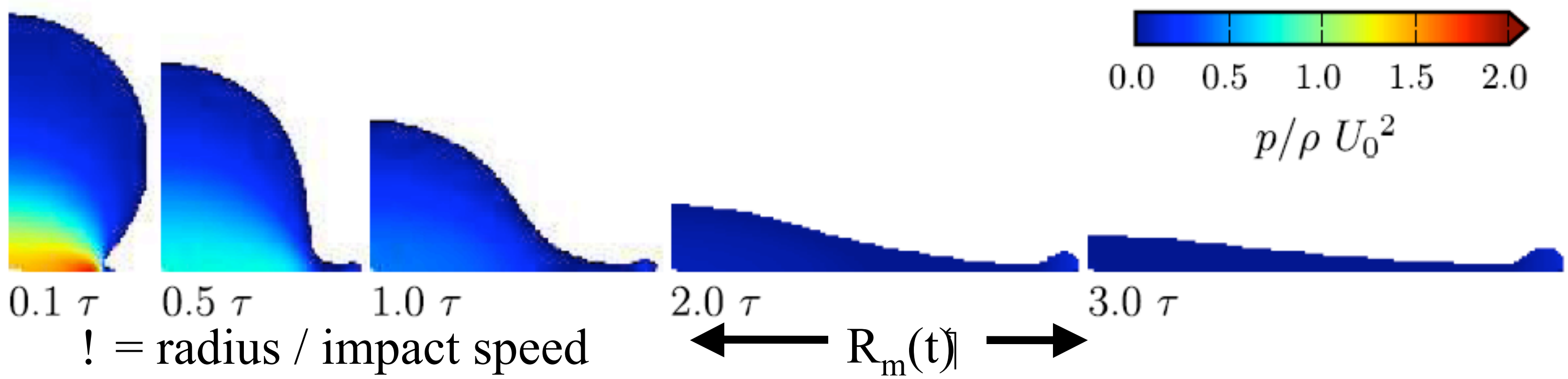




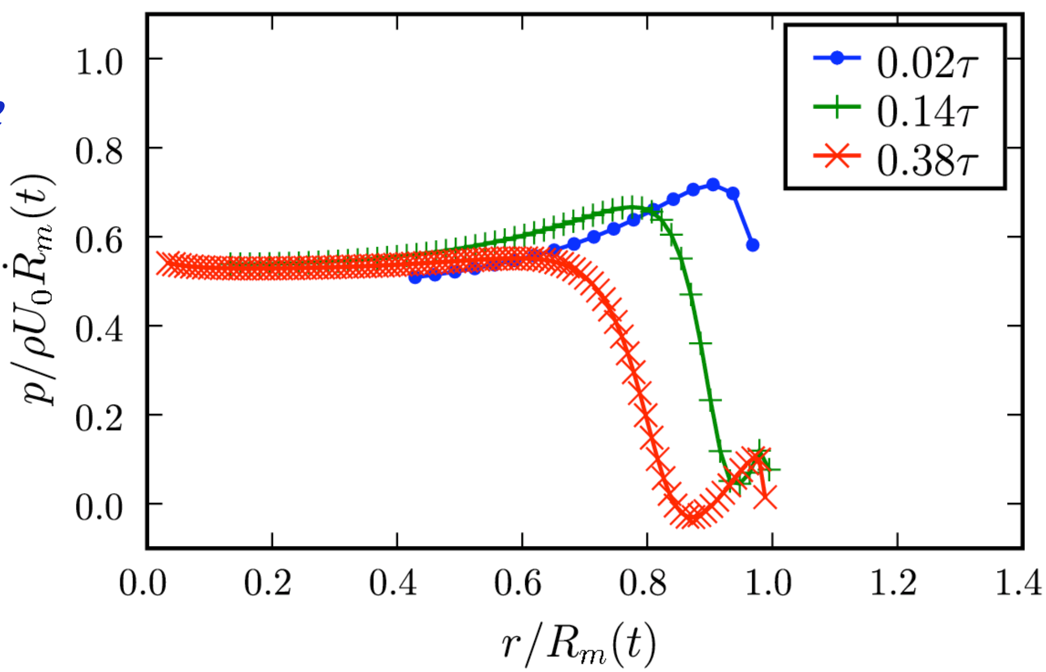
Small amount of air trapped between drops
- No effect on top surface

7. Pressure variation at early times

volume conservation ➔ pressure variation ➔ liquid ejected radially

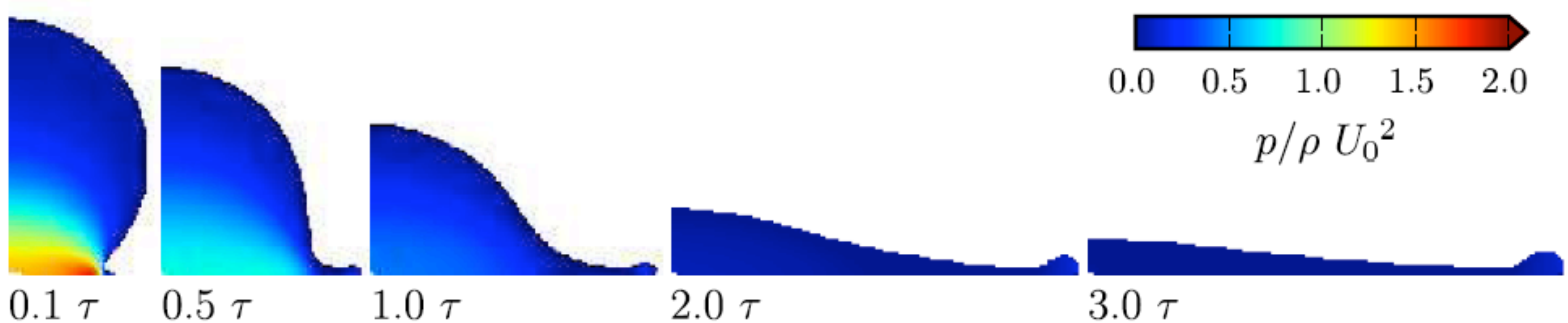


At early times, pressure variation scales with vertical impact speed & radial expansion



8. Pressure variations at late times

volume conservation ➔ pressure variation ➔ liquid ejected radially

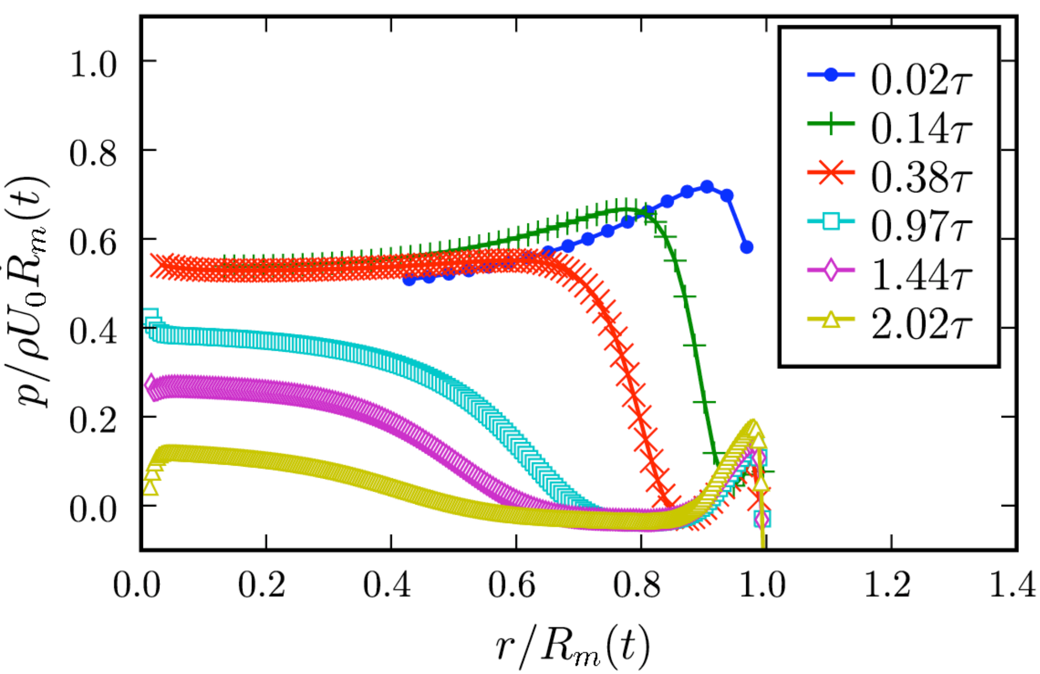


! = radius / impact speed

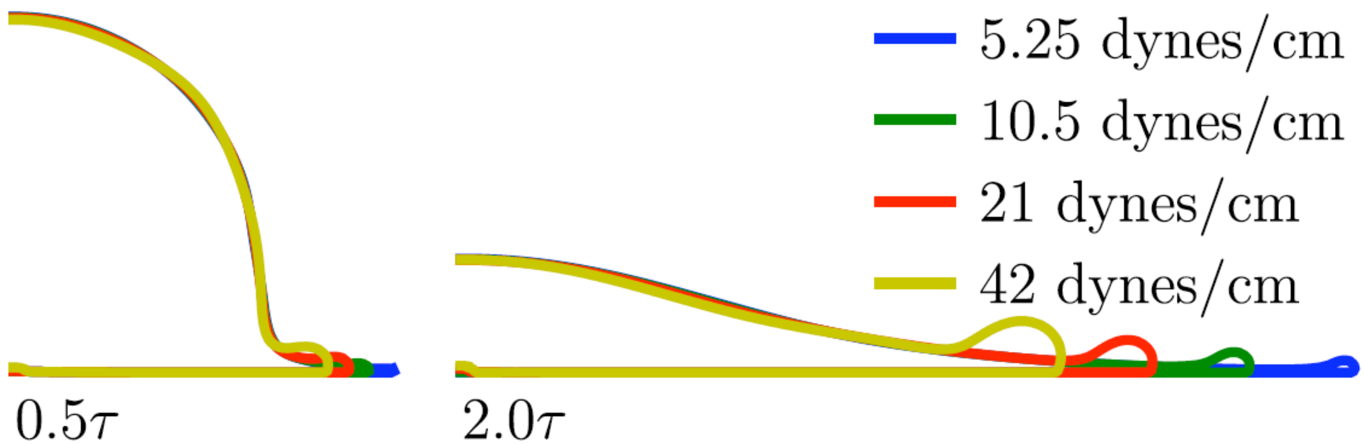
⟵ $R_m(t)$ ⟶

At late times expansion slows but downward fall slows more dramatically

➔ Pressure decreases more rapidly than early-time scaling form



9. Surface tension confined to rim & slows expansion



Conclusions

High-speed impact demonstrates fluid properties of drops

Dynamics dominated by inertia
- High pressure at impact plane brakes fall, expels sheet

Surface tension slows expansion