libWetHair

A Multi-Scale Model for Simulating Liquid-Hair Interactions

YUN (RAYMOND) FEI, HENRIQUE TELES MAIA, CHRISTOPHER BATTY, CHANGXI ZHENG, EITAN GRINSPUN
COLUMBIA UNIVERSITY AND UNIVERSITY OF WATERLOO

http://libwethair.info

Paper, Executables, Code, and More

http://libwethair.info

Paper, Executables, Code, and More

http://libwethair.info

Paper, Executables, Code, and More

http://libwethair.info

Paper, Executables, Code, and More


cohesion


cohesion
flow along hairs


cohesion
flow along hairs
dripping

Related Work

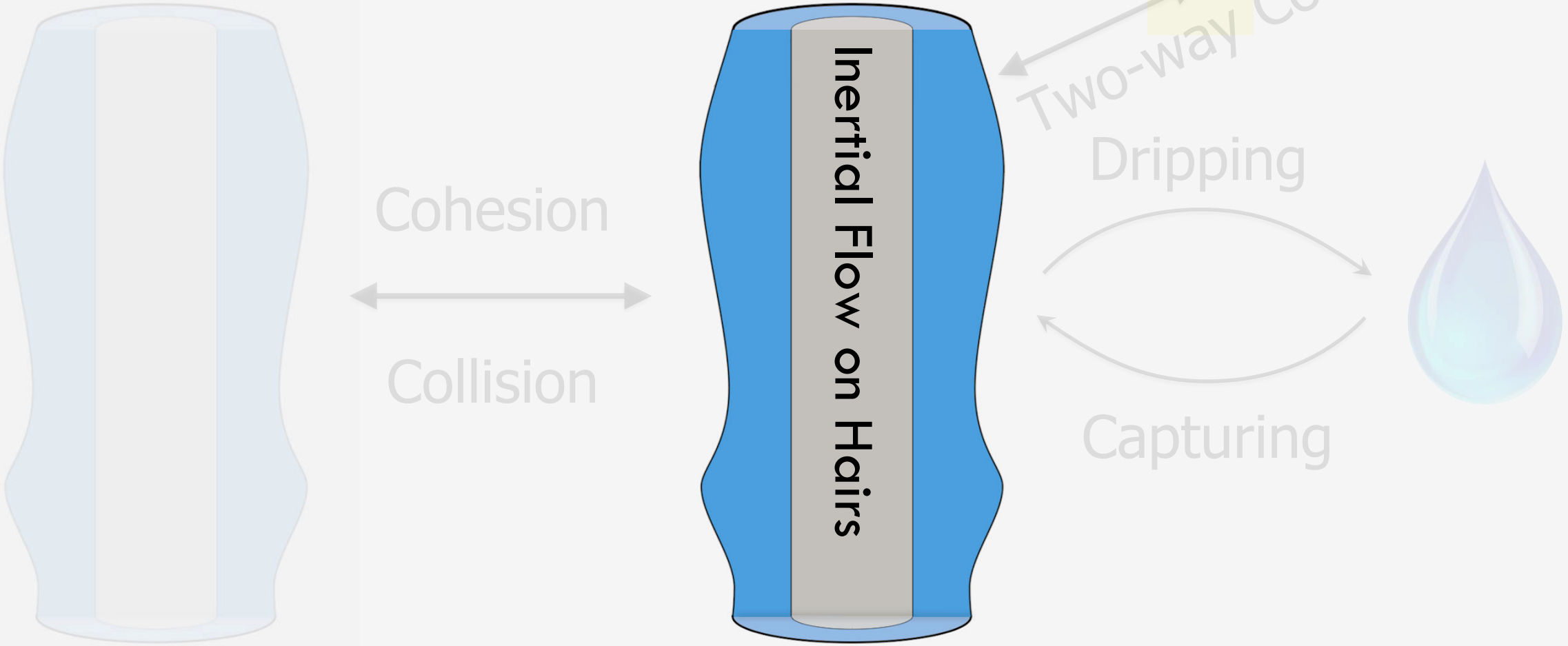
[Ward et al. 2004]

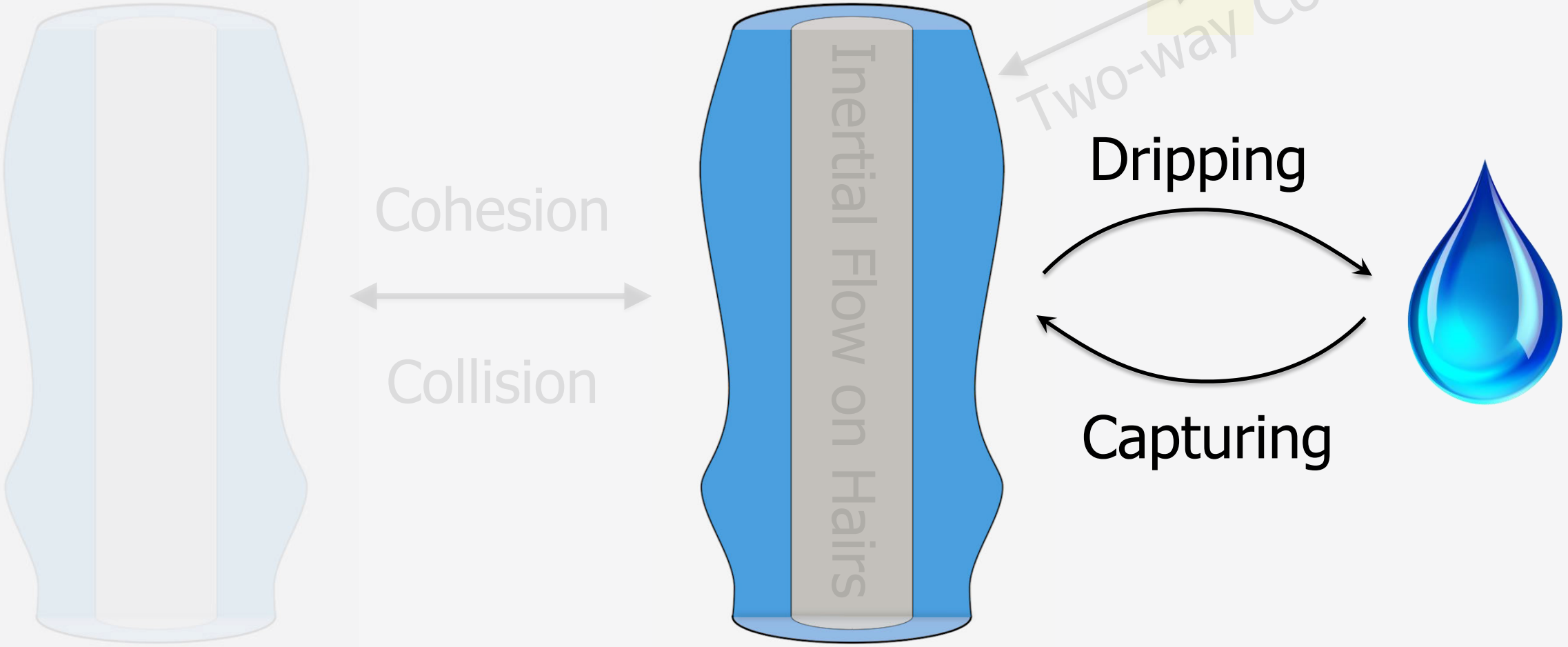
[Bertails-Descoubes et al. 2005]

Related Work

[Rungjiratananon et al. 2012]

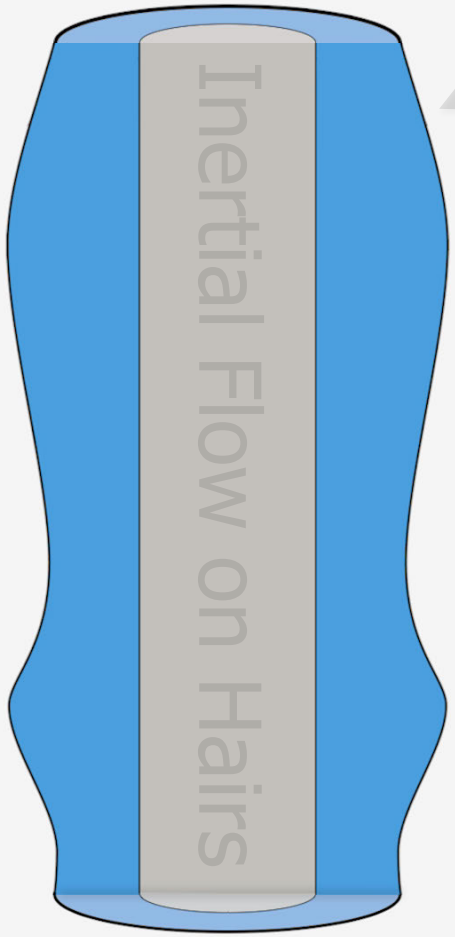
[Lin 2015]


Cohesion
Collision
Inertial Flow on Hairs
Two-way Coupling
Dripping
Capturing


Two-way Coupling
Cohesion
Collision
Inertial Flow on Hairs
Dripping
Capturing

Cohesion

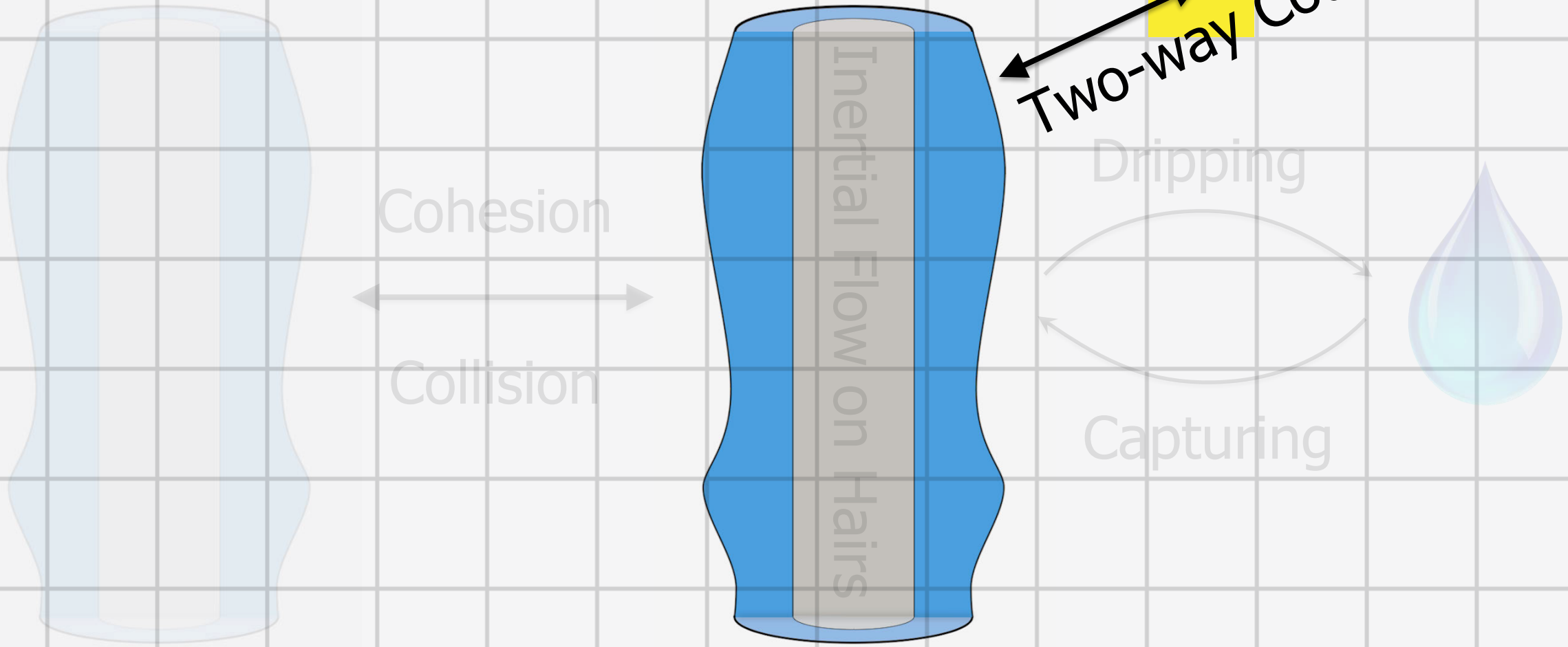
Collision

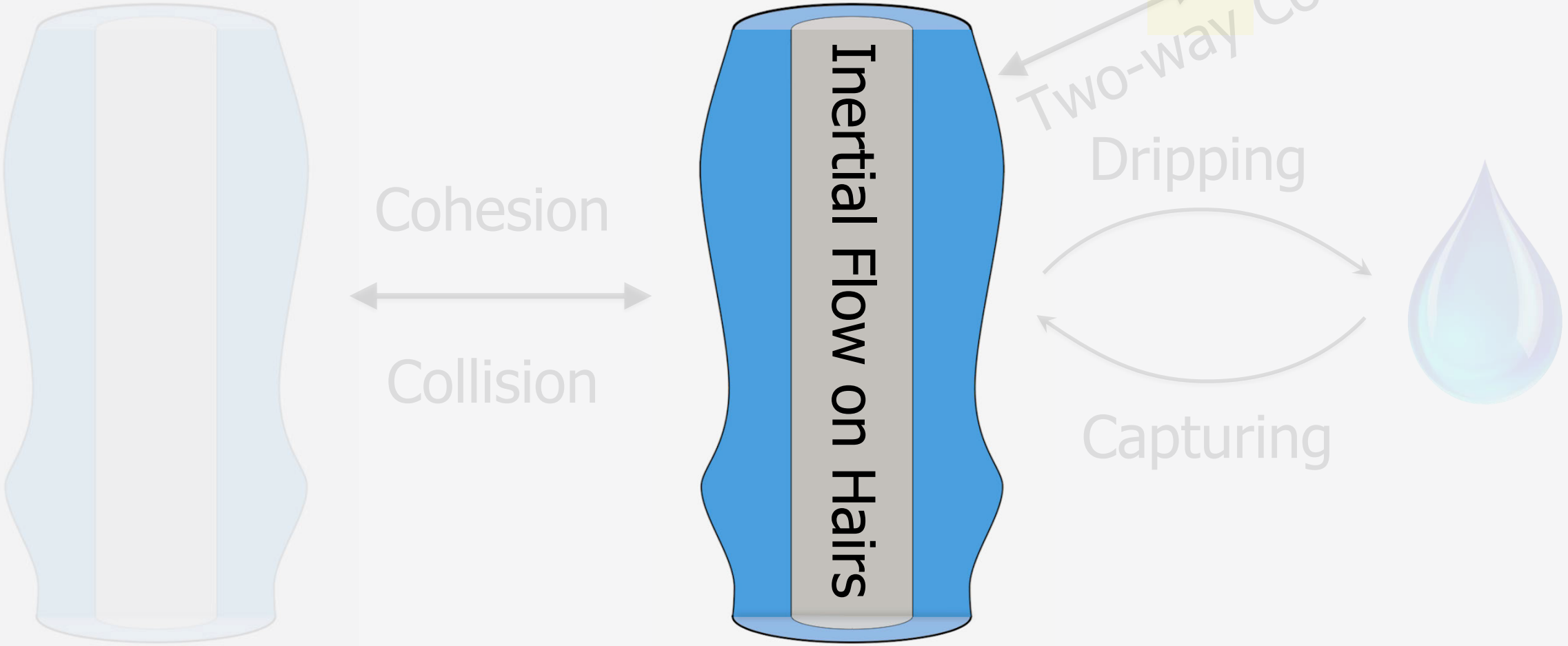


Two-way Coupling

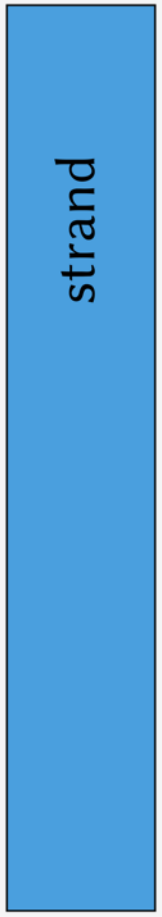
Dripping

Capturing

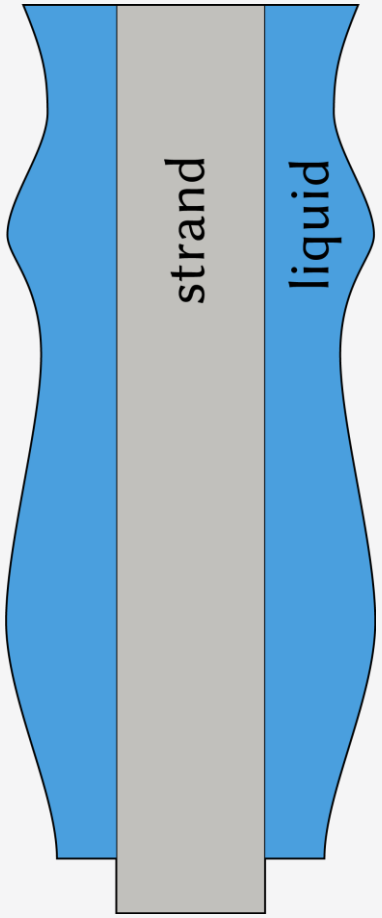

Two-way Coupling
Inertial Flow on Hairs
Cohesion
Collision
Dripping
Capturing


Cohesion
Collision
Inertial Flow on Hairs
Two-way Coupling
Dripping
Capturing

Where does the liquid live?

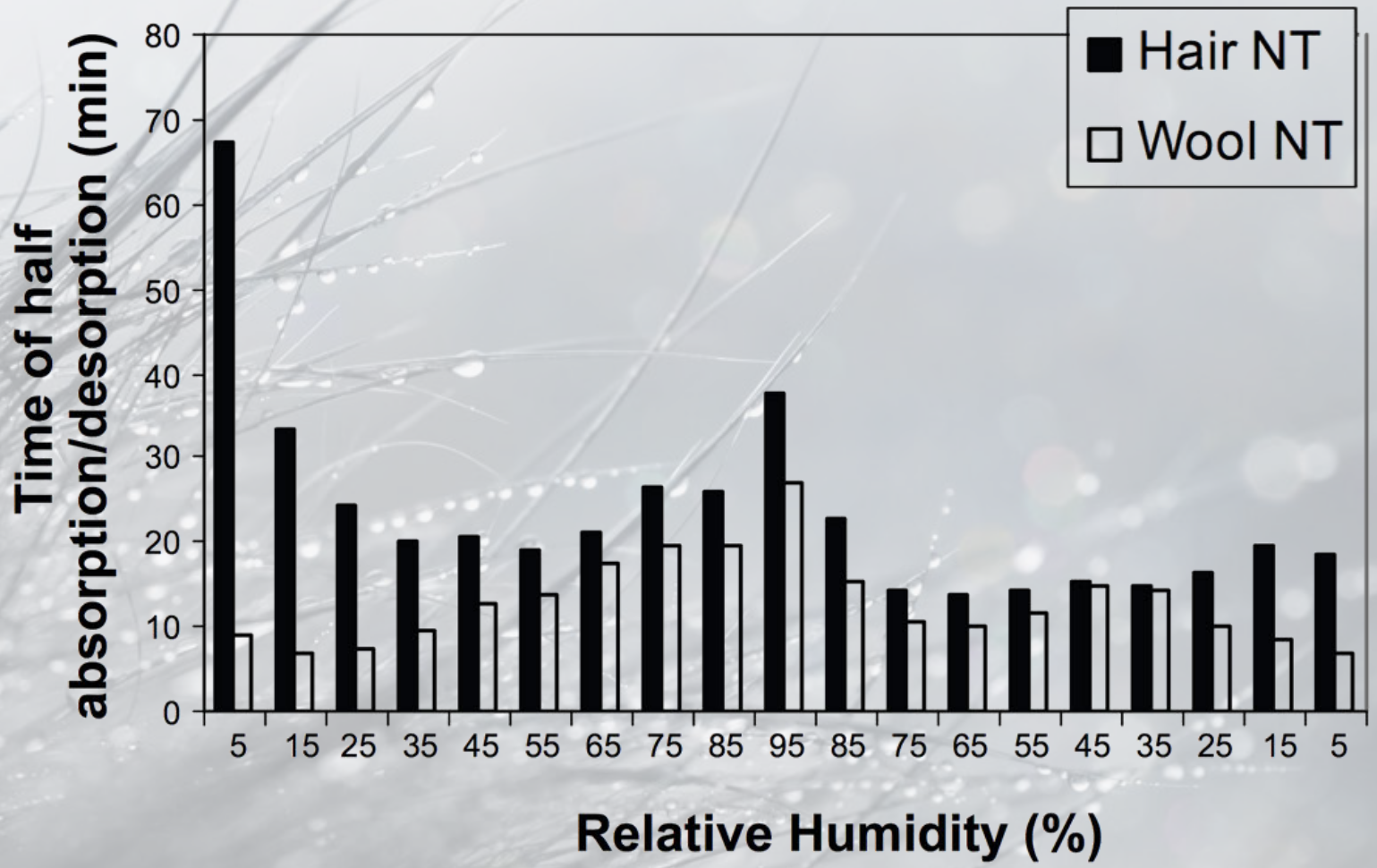


Liquid Inside Hair

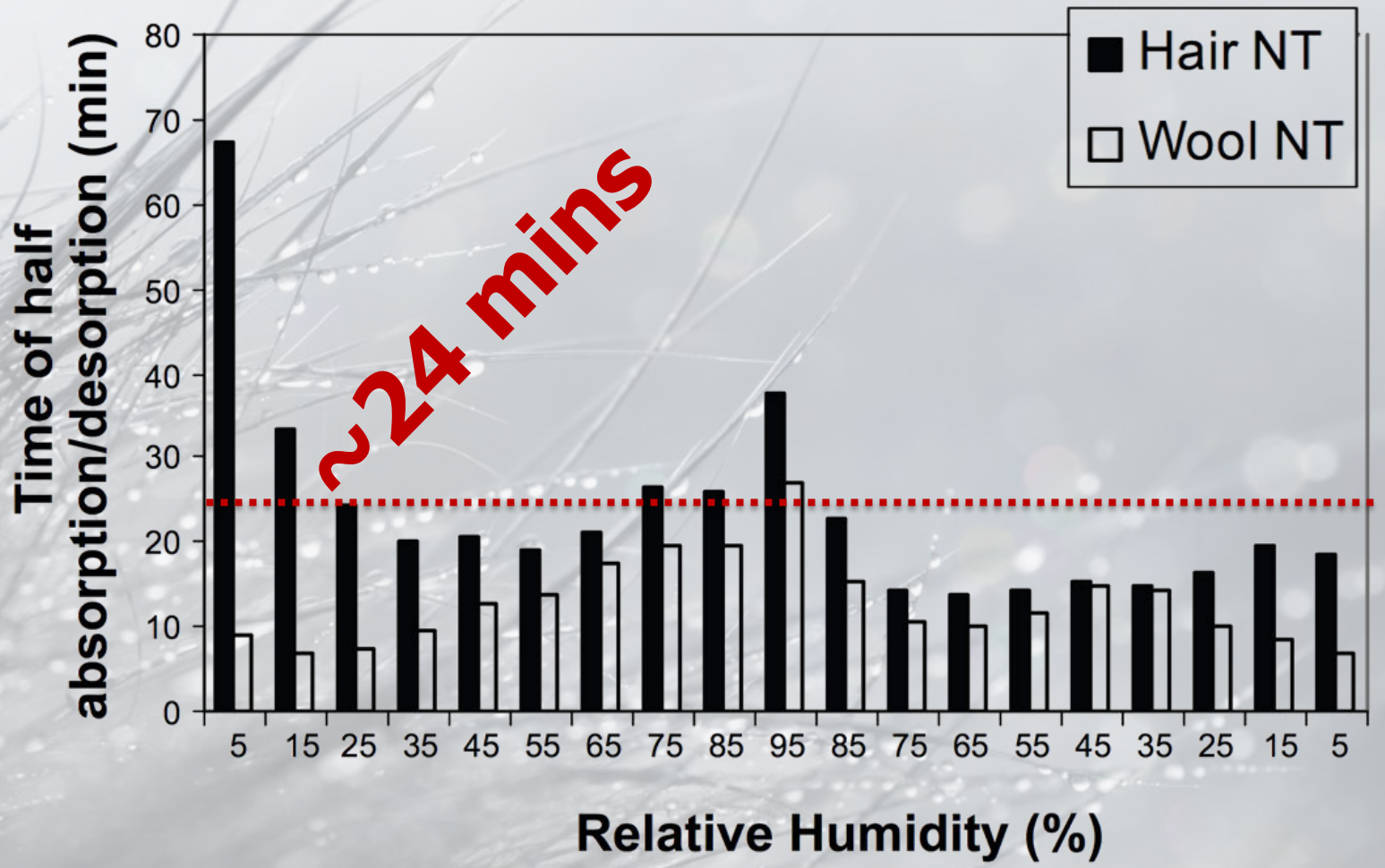


On Hair Surface

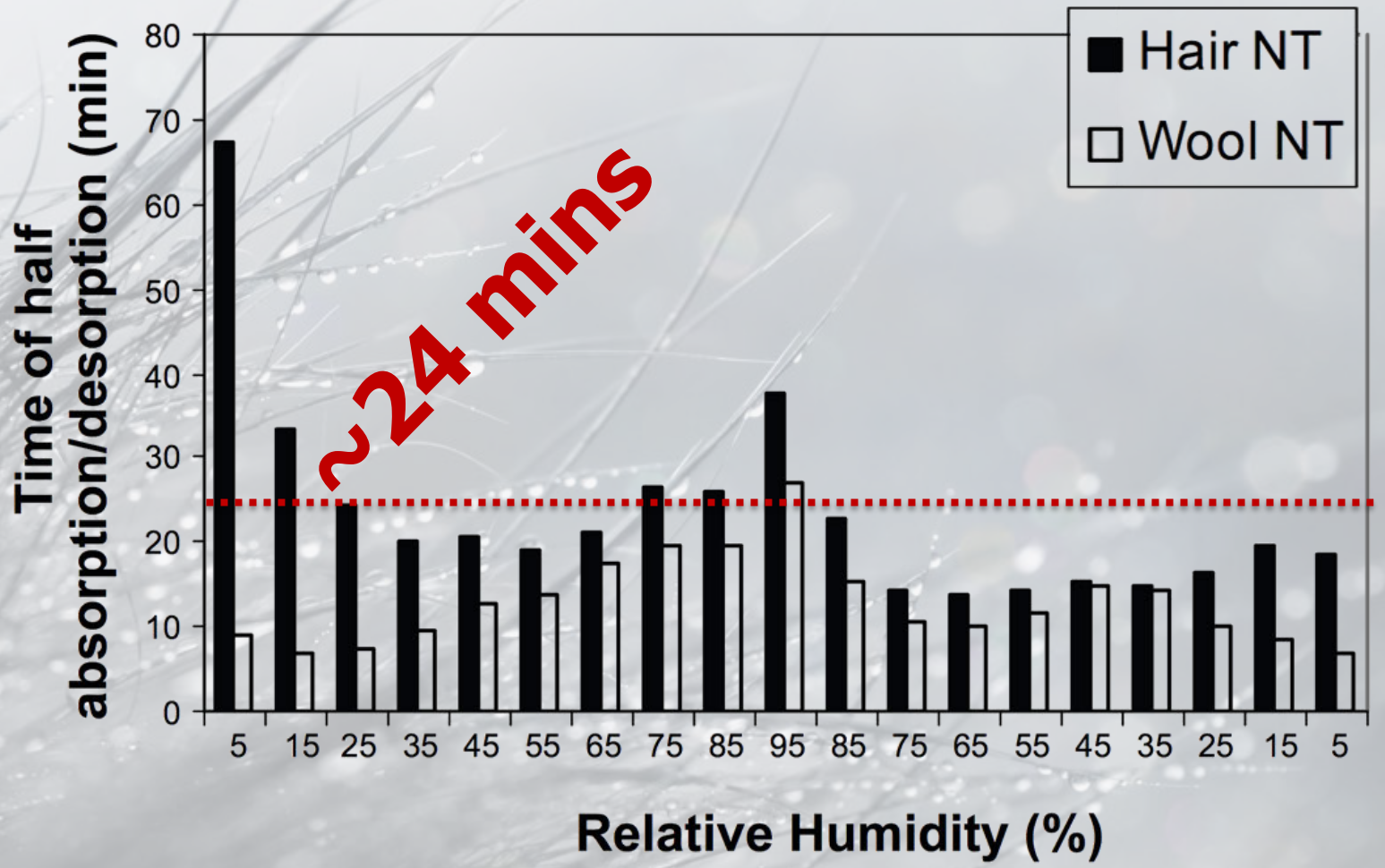
Image Courtesy Of La Corivo



Barba, C., et al. "Moisture sorption/desorption of protein fibres." *Thermochimica acta* 552 (2013): 70-76.

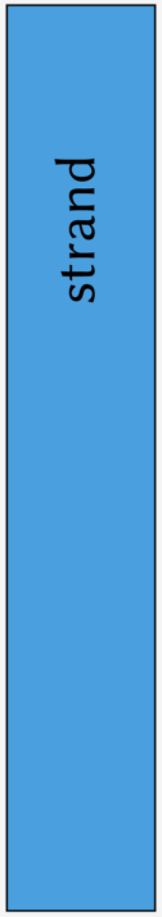


Barba, C., et al. "Moisture sorption/desorption of protein fibres." *Thermochimica acta* 552 (2013): 70-76.

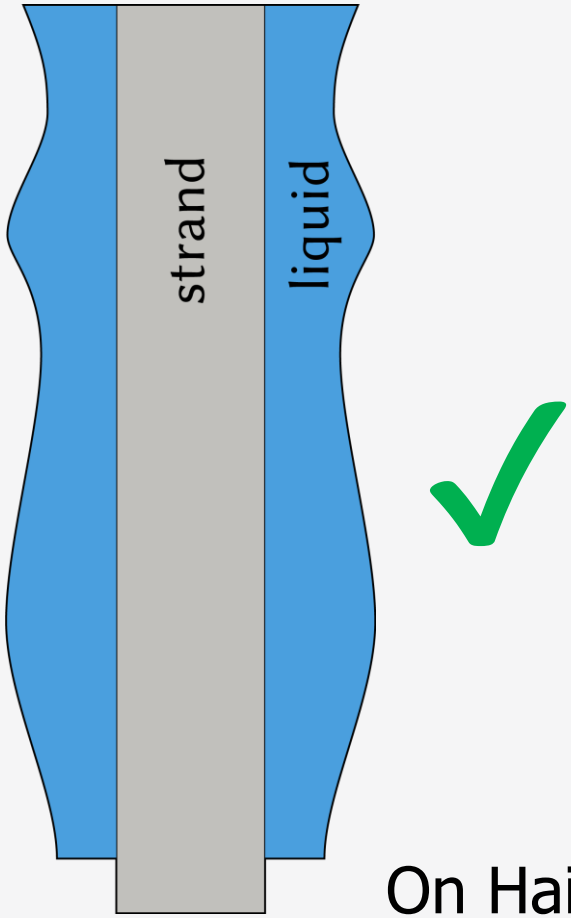


Barba, C., et al. "Moisture sorption/desorption of protein fibres." *Thermochimica acta* 552 (2013): 70-76.

Where does the liquid live?

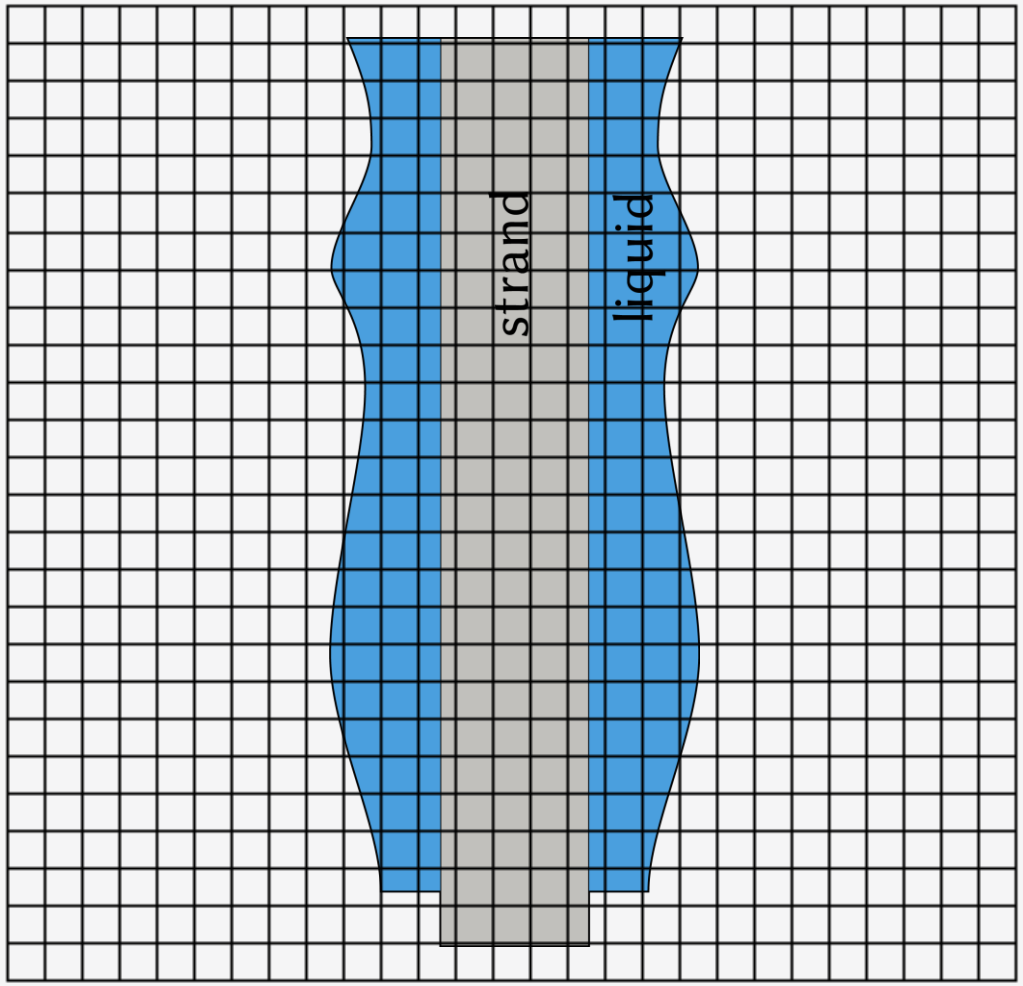


Liquid Inside Hair



On Hair Surface

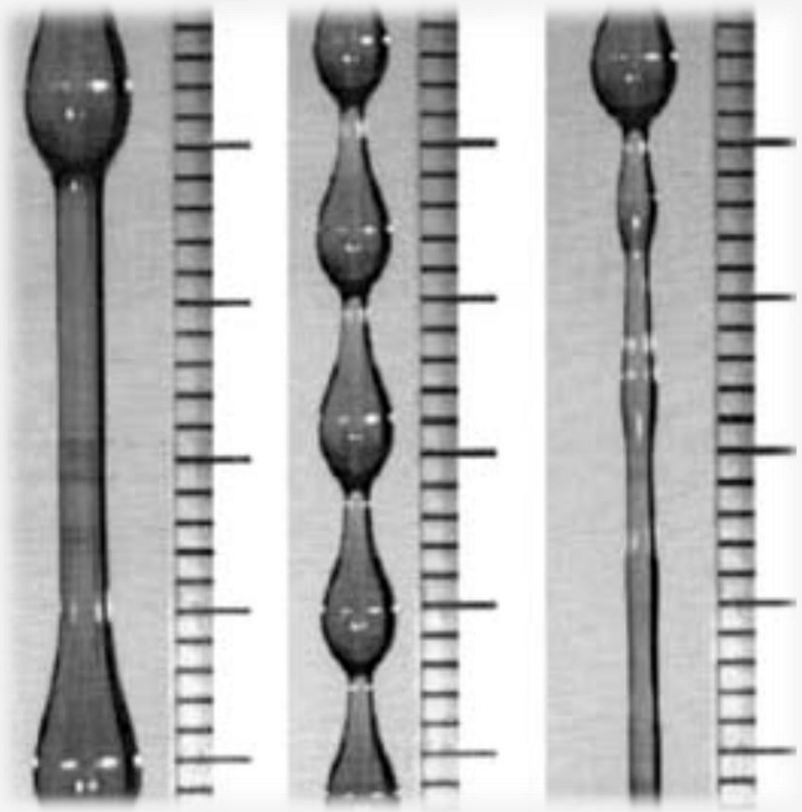
Simulating Liquid on Hair Surface



Full discretized simulation is too costly ✕

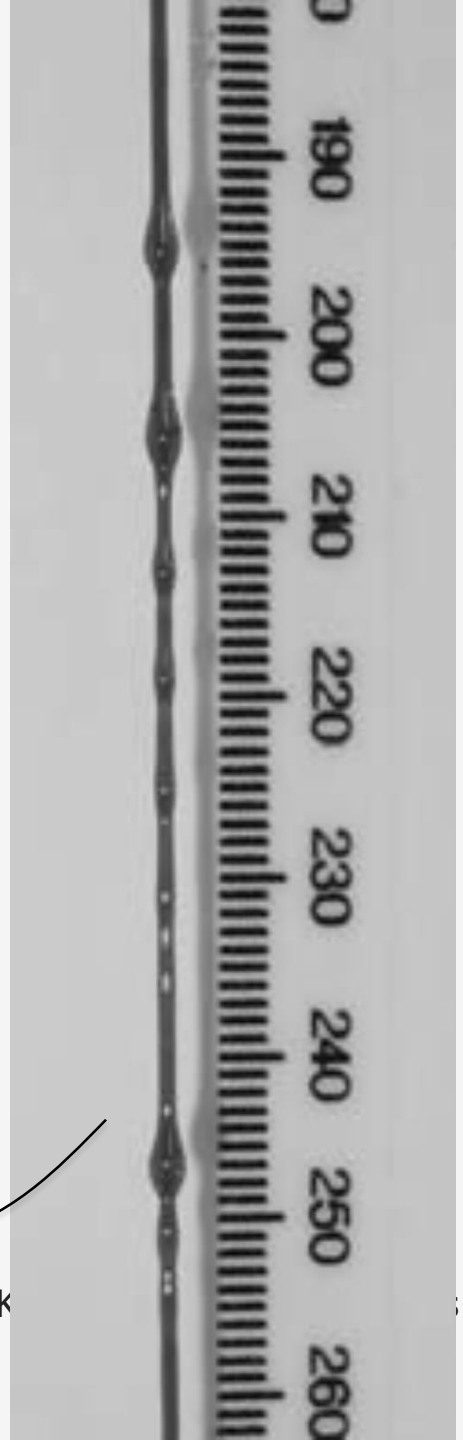
Image Courtesy of Alexander Demianchuk / Reuters

- ✓ Support Inertia & Sudden Accelerations
- Need Surface Tension
- Specifically Designed for Thin Liquid



- ✓ Support Inertia & Sudden Accelerations
- ✓ Need Surface Tension
- Specifically Designed for Thin Liquid

Craster, R. V., and O. K. Matar. "On viscous beads flowing down a vertical fibre." *Journal of Fluid Mechanics* 553 (2006): 85-105.



Hair

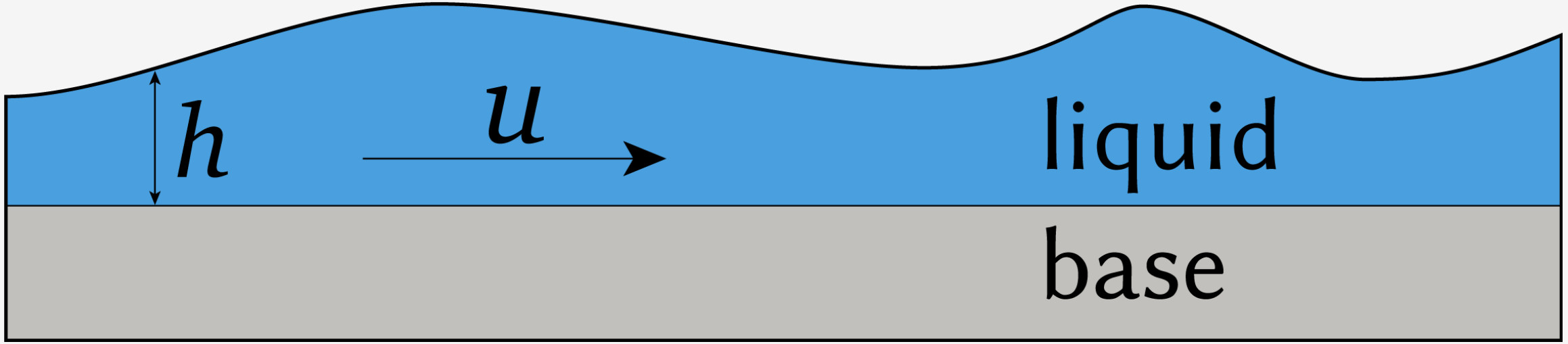
- ✓ Support Inertia & Sudden Accelerations
- ✓ Need Surface Tension
- ✓ Specifically Designed for Thin Liquid

Craster, R. V., and O. K flowing down a vertical fibre." *Journal of Fluid Mechanics* 553 (2006): 85-105.

Shallow Water Equation

Momentum Equation

$$\underbrace{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x}}_{\text{Inertia}} = \underbrace{-\frac{1}{\rho}\frac{\partial p}{\partial x}}_{\text{Surface Tension}} + \underbrace{a_{\text{ext}}}_{\text{External Force (Gravity)}}$$

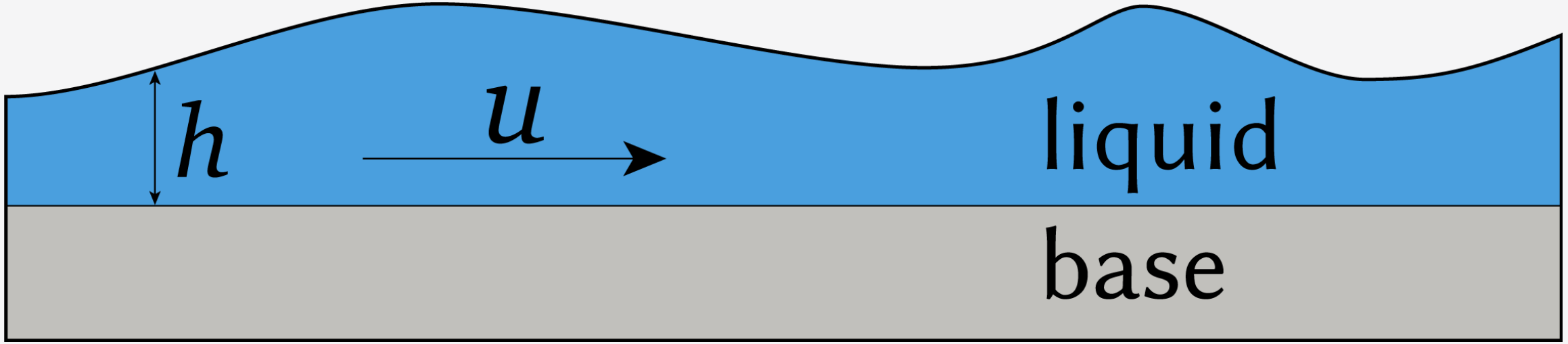


Shallow Water Equation

Momentum Equation

$$\underbrace{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x}}_{\text{Inertia}} = \underbrace{-\frac{1}{\rho}\frac{\partial p}{\partial x}}_{\text{Surface Tension}} + \underbrace{a_{\text{ext}}}_{\text{External Force (Gravity)}}$$

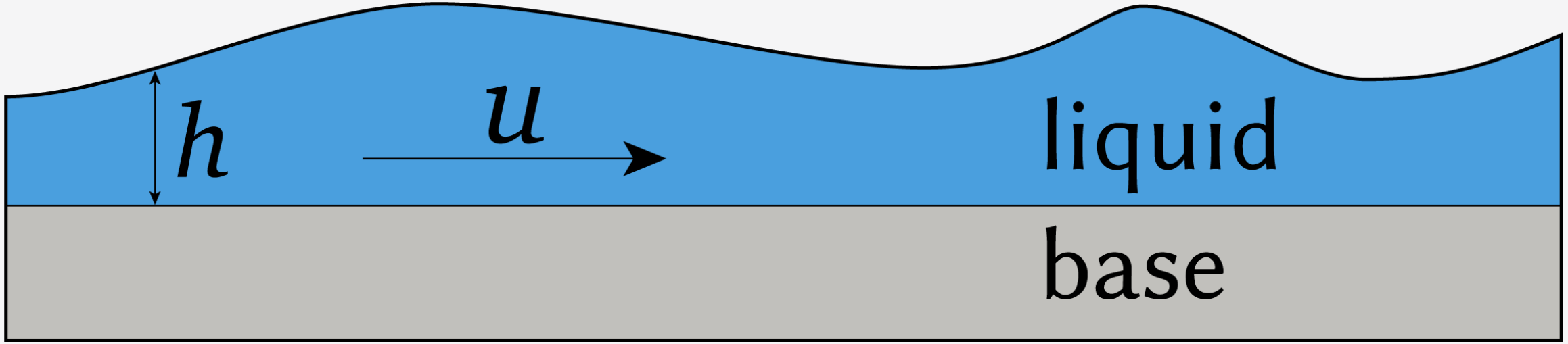
✓ Inertia



Shallow Water Equation

Momentum Equation

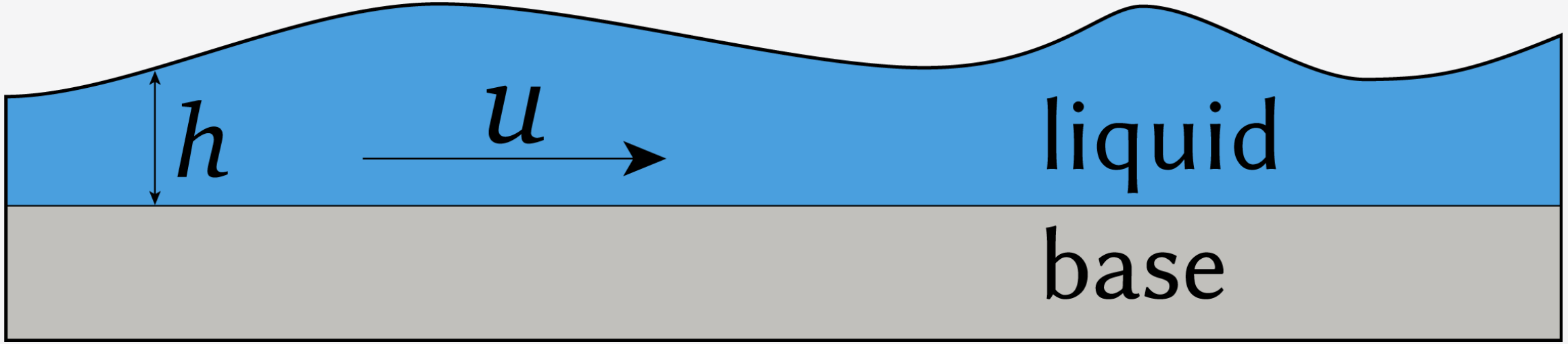
$$\underbrace{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x}}_{\checkmark\ \text{Inertia}} = \underbrace{-\frac{1}{\rho}\frac{\partial p}{\partial x}}_{\checkmark\ \text{Surface Tension}} + \underbrace{a_{\text{ext}}}_{\text{External Force (Gravity)}}$$



Shallow Water Equation

Momentum Equation

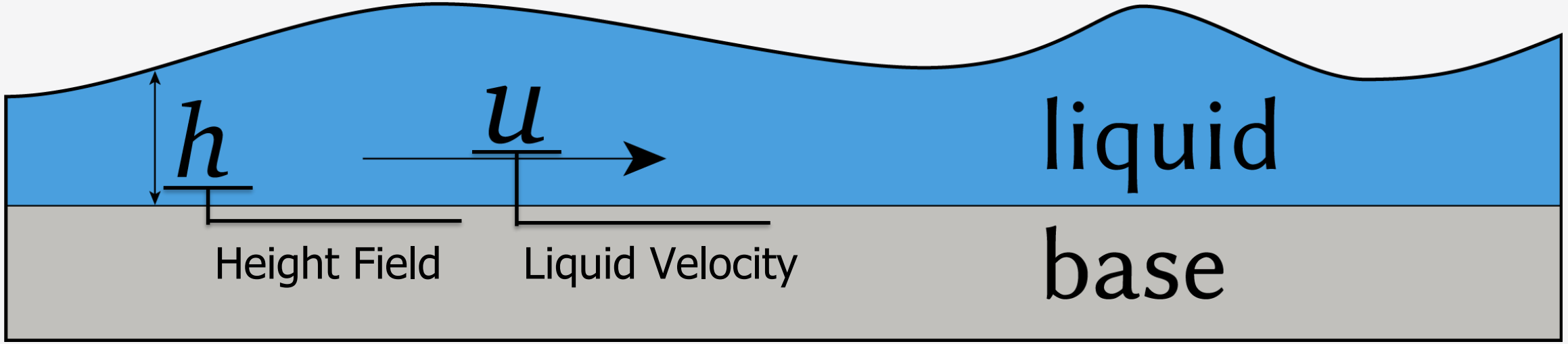
$$\underbrace{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x}}_{\text{✓ Inertia}} = \underbrace{-\frac{1}{\rho}\frac{\partial p}{\partial x}}_{\text{✓ Surface Tension}} + \underbrace{a_{\text{ext}}}_{\text{✓ External Force (Gravity)}}$$



Shallow Water Equation

Continuity Equation for Mass

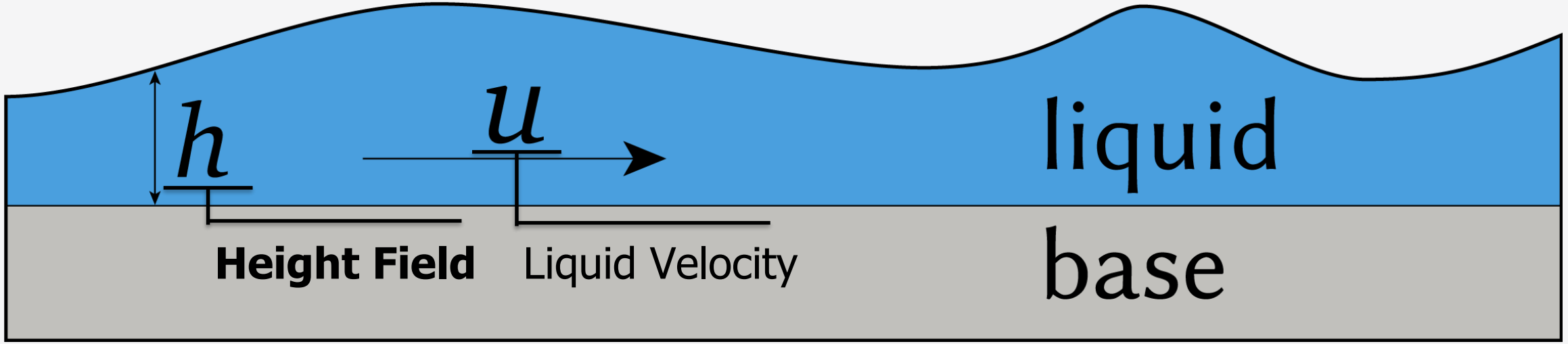
$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} = 0$$



Shallow Water Equation

Continuity Equation for Mass

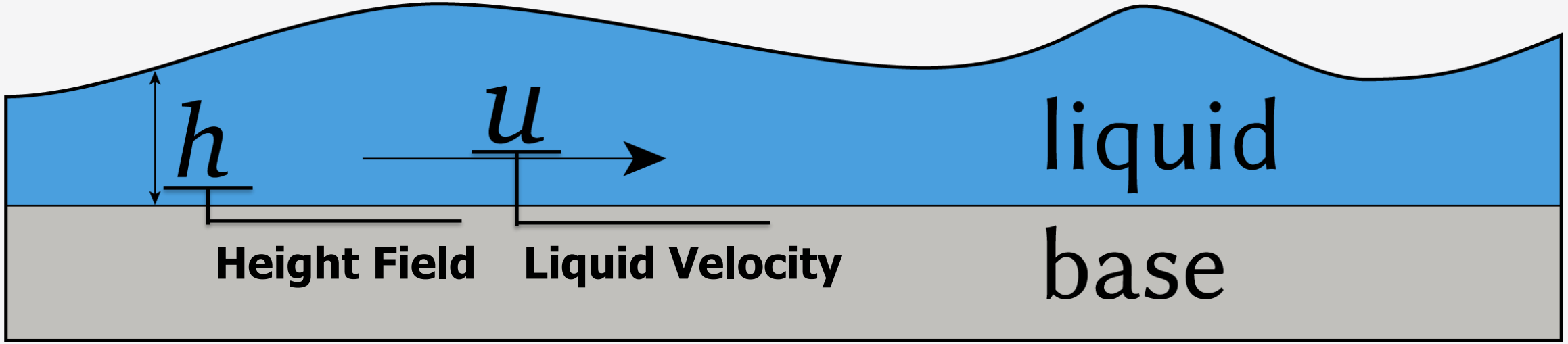
$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} = 0$$



Shallow Water Equation

Continuity Equation for Mass

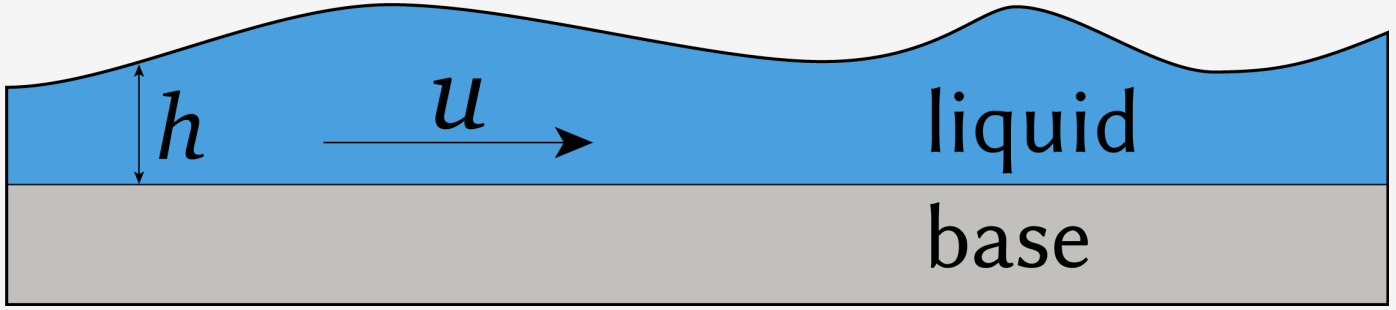
$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} = 0$$



Shallow Water Equation

Continuity Equation for Mass

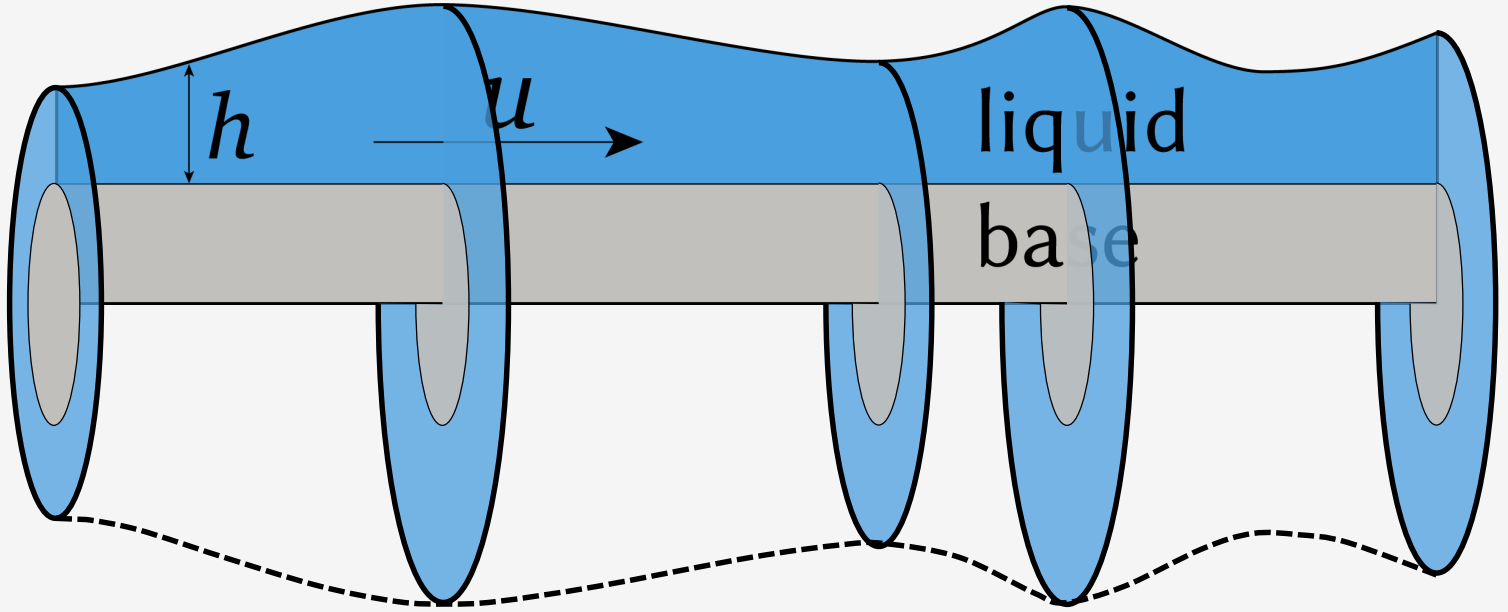
$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} = 0$$



Reduced-Liquid Equation on Hair

Continuity Equation for Mass

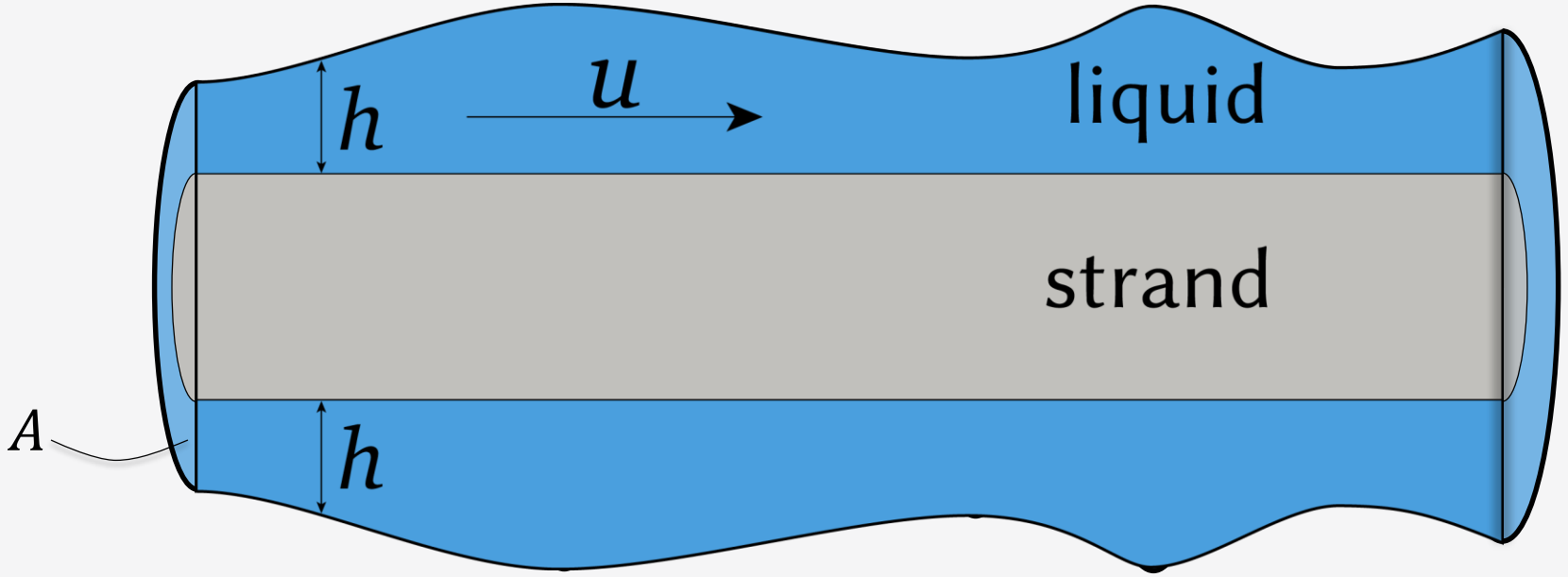
$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} = 0$$

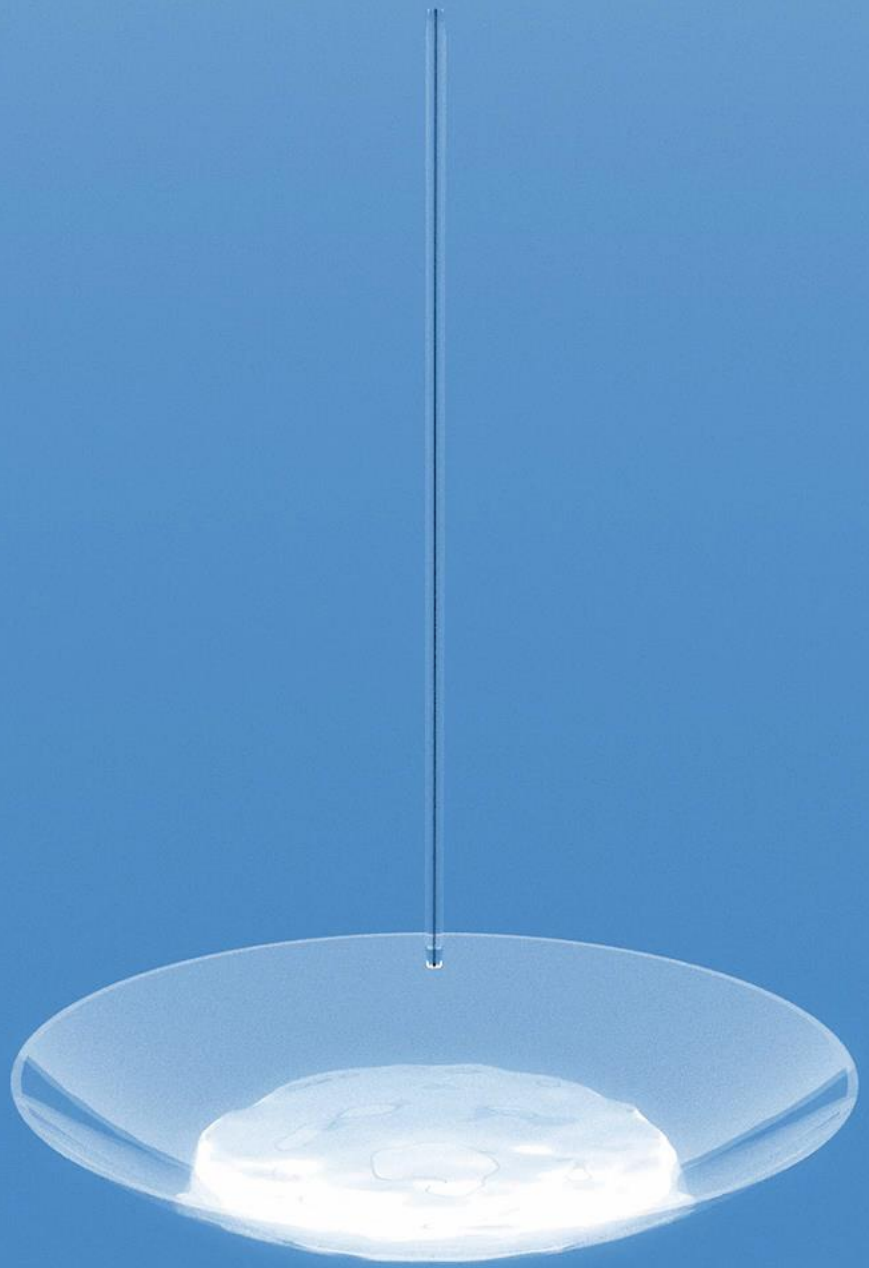


Reduced-Liquid Equation on Hair

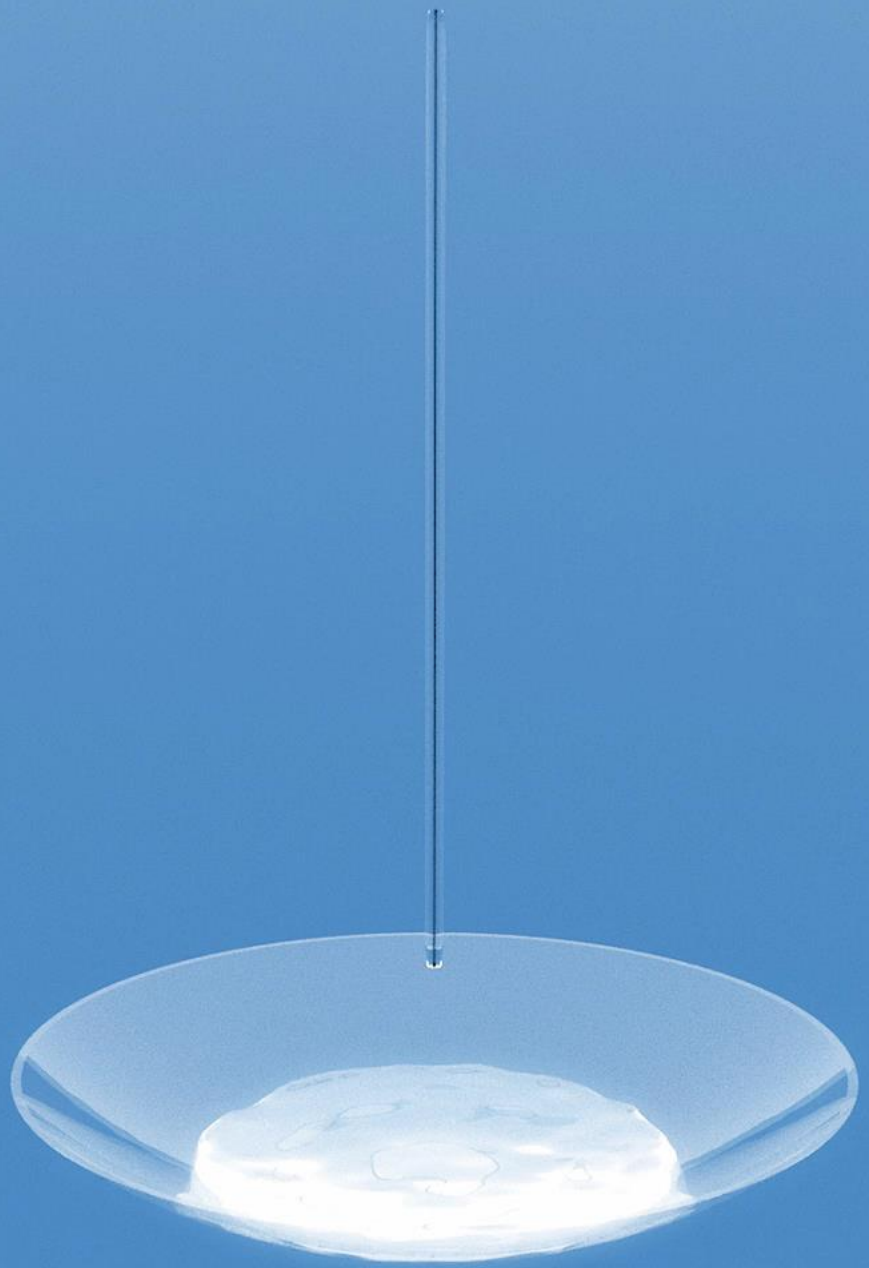
Continuity Equation for Mass

$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} = 0 \rightarrow \frac{\partial A}{\partial t} + u\frac{\partial A}{\partial x} = 0$$





Flow OFF

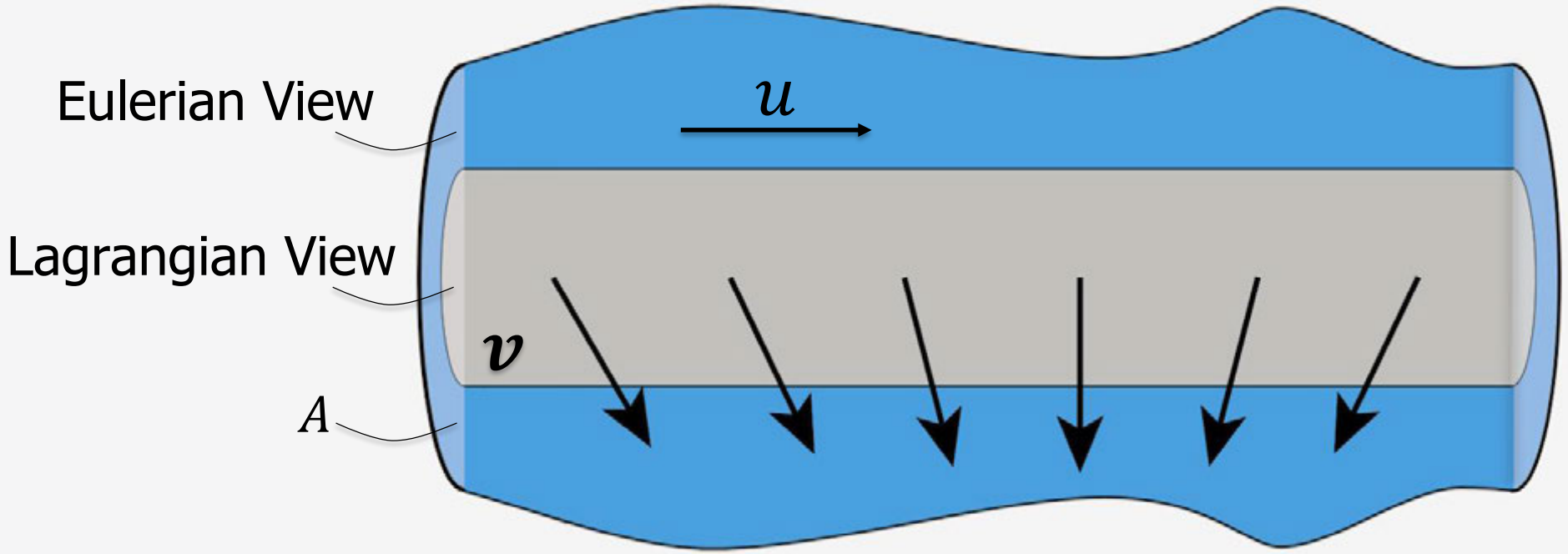


Flow ON

Momentum Conservation for Eulerian-on-Lagrangian Flow

Continuity Equation for Extrinsic Momentum

$$\frac{\partial}{\partial t}(A\boldsymbol{v}) = -\frac{\partial}{\partial x}(Au\boldsymbol{v})$$

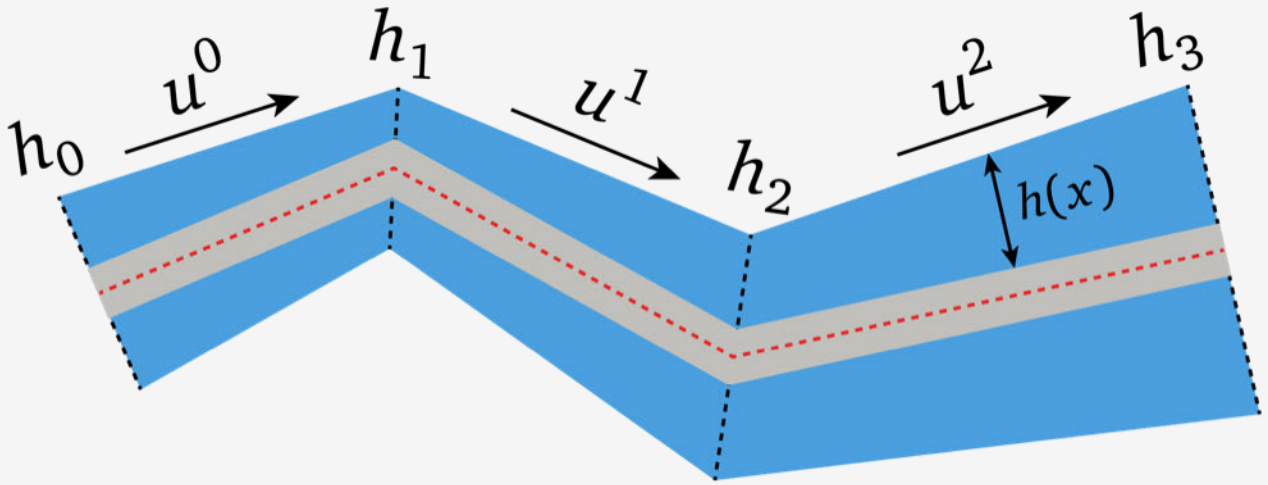


Fan, Ye, et al. "Eulerian-on-Lagrangian simulation." *ACM Transactions on Graphics (TOG)* 32.3 (2013): 22.

Ignore Hair Momentum Change

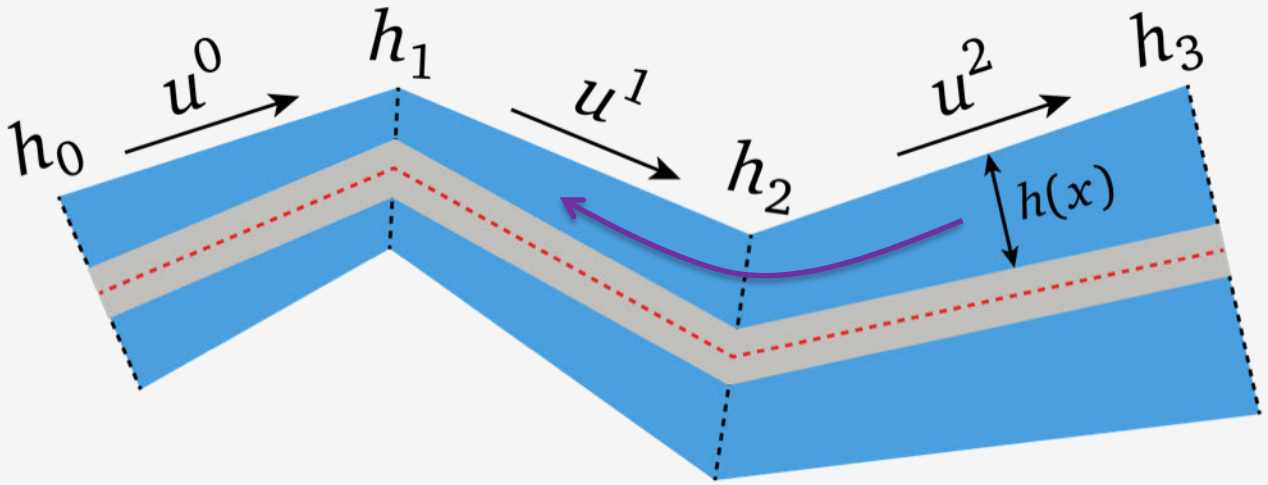
Our Method

Discretization & Pipeline



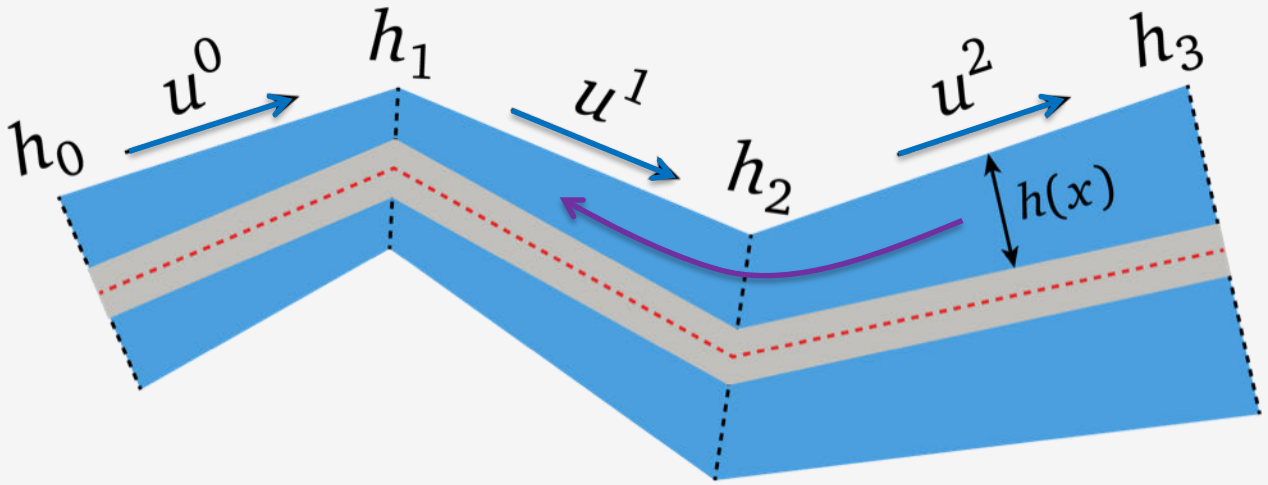
1. Semi-Lagrangian advection
2. Add external force, pressure, and update flow velocity u
3. Solve for the continuity equations
4. Update hair velocity.

Discretization & Pipeline



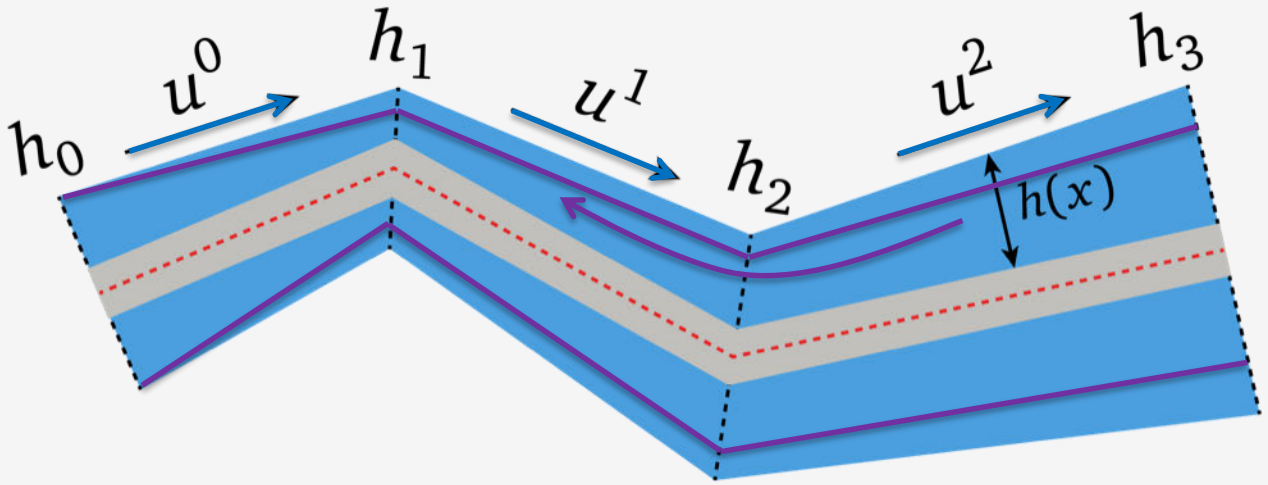
1. **Semi-Lagrangian advection**
2. Add external force, pressure, and update flow velocity u
3. Solve for the continuity equations
4. Update hair velocity.

Discretization & Pipeline



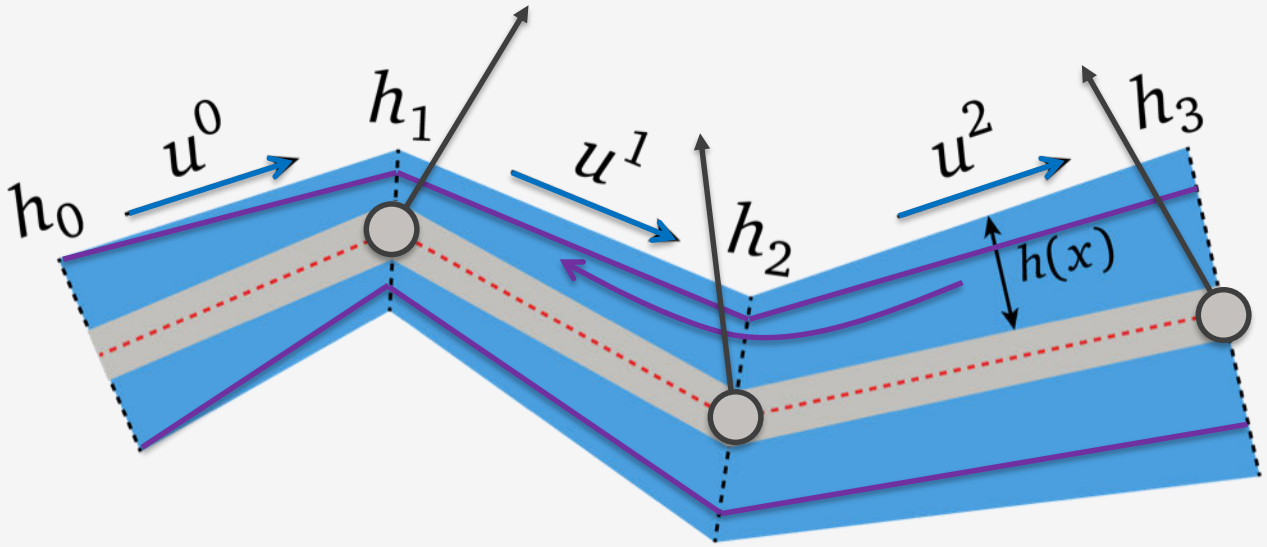
1. **Semi-Lagrangian advection**
2. **Add external force, pressure, and update flow velocity u**
3. Solve for the continuity equations
4. Update hair velocity.

Discretization & Pipeline

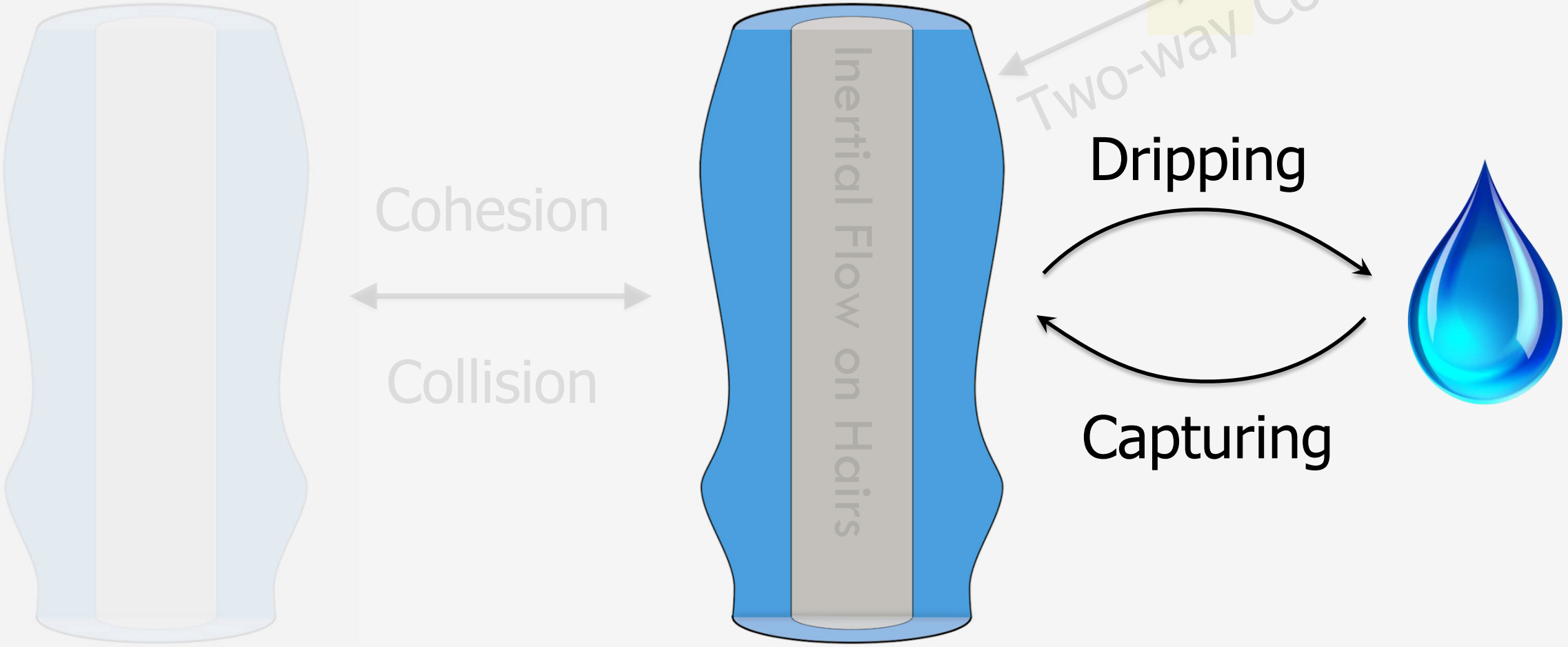


1. **Semi-Lagrangian advection**
2. **Add external force, pressure, and update flow velocity u**
3. **Solve for the continuity equations**
4. Update hair velocity.

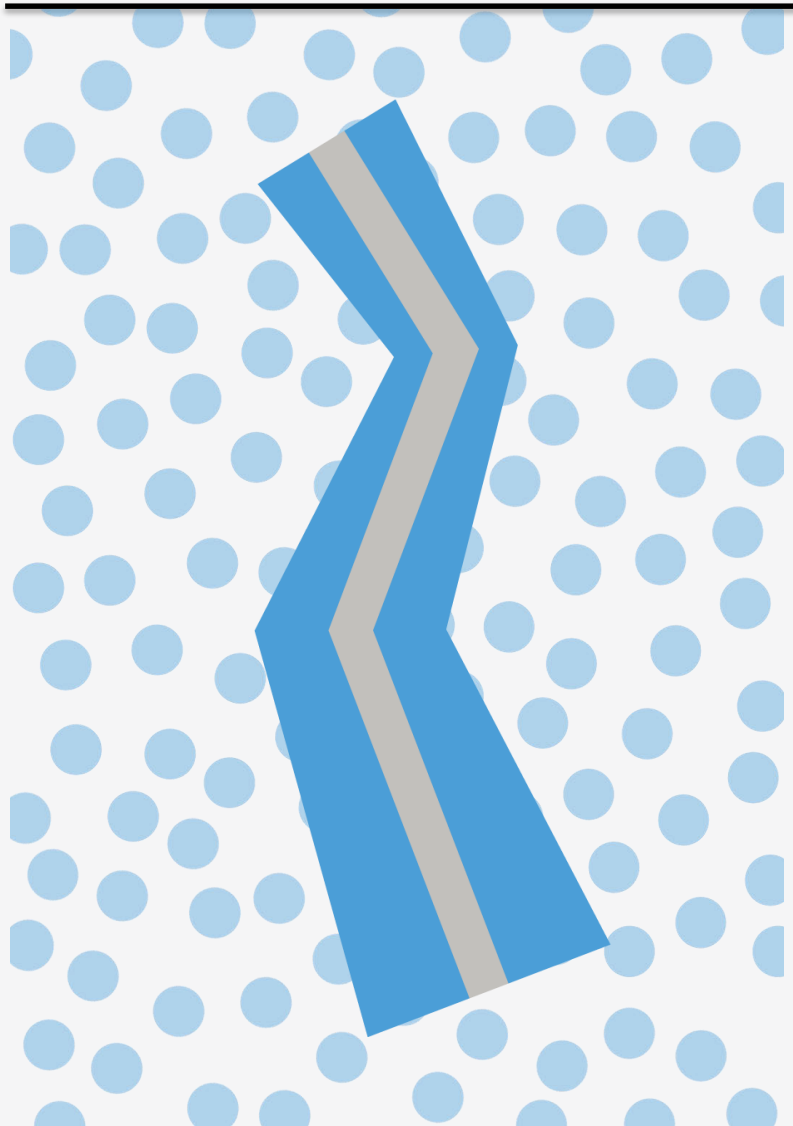
Discretization & Pipeline



1. Semi-Lagrangian advection
2. Add external force, pressure, and update flow velocity u
3. Solve for the continuity equations
4. Update hair velocity.


Cohesion
Collision
Inertial Flow on Hairs
Two-way Coupling
Dripping
Capturing

Capturing Reduced-Liquid



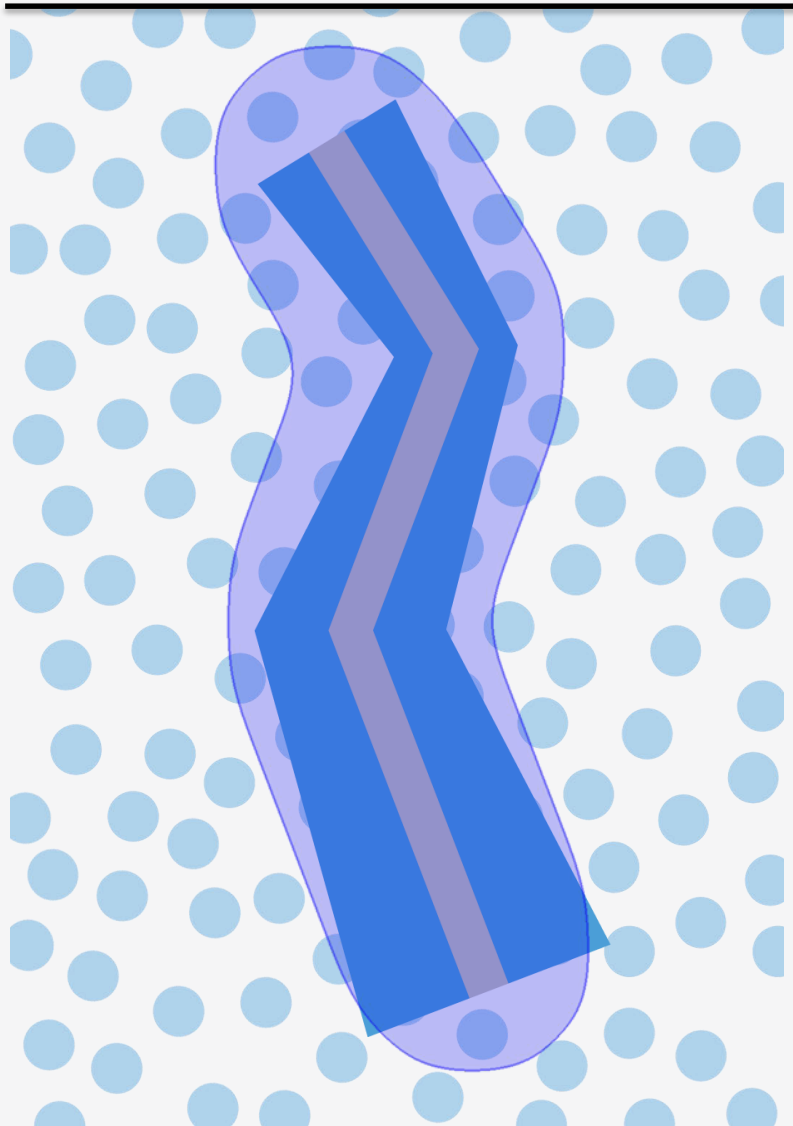
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Capturing Reduced-Liquid



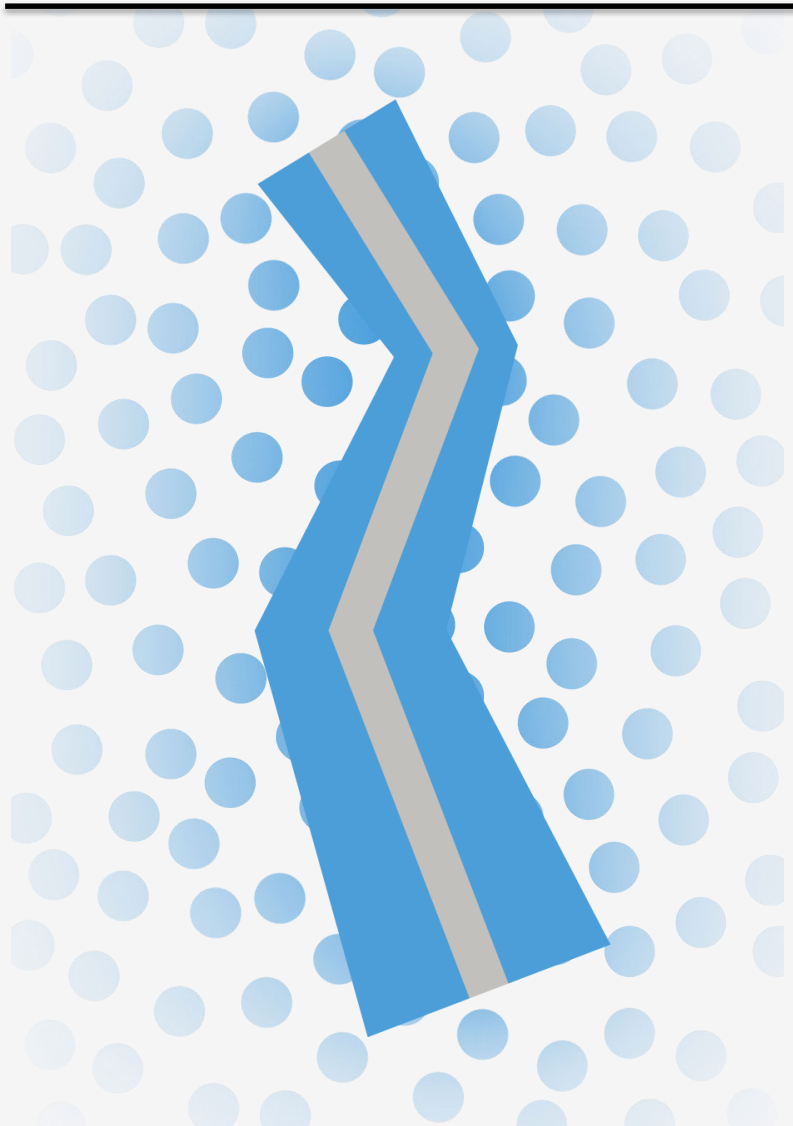
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Capturing Reduced-Liquid



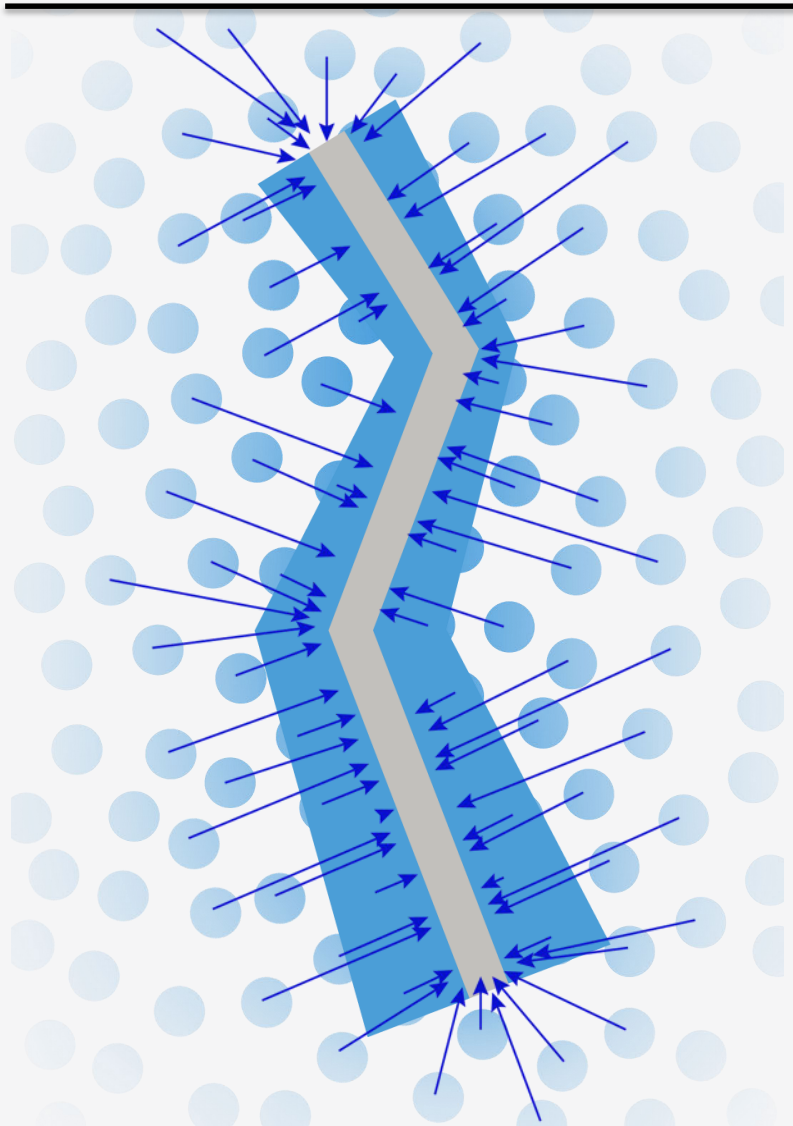
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Capturing Reduced-Liquid



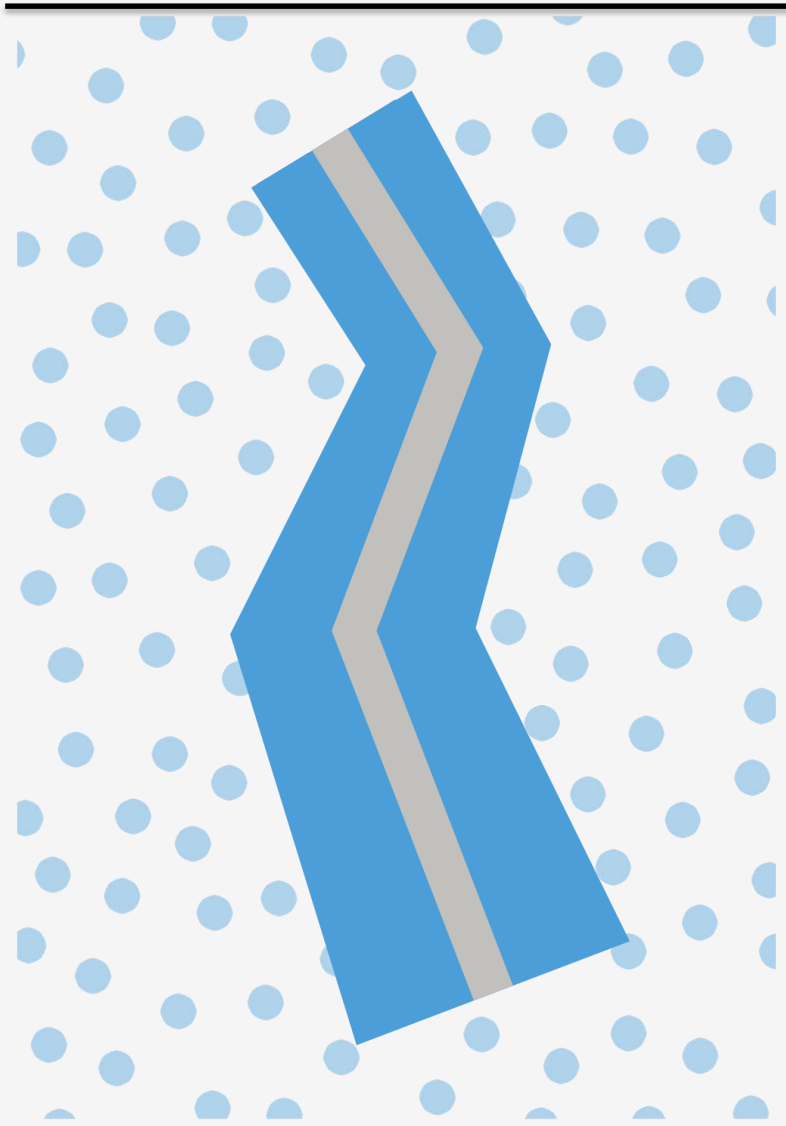
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Capturing Reduced-Liquid



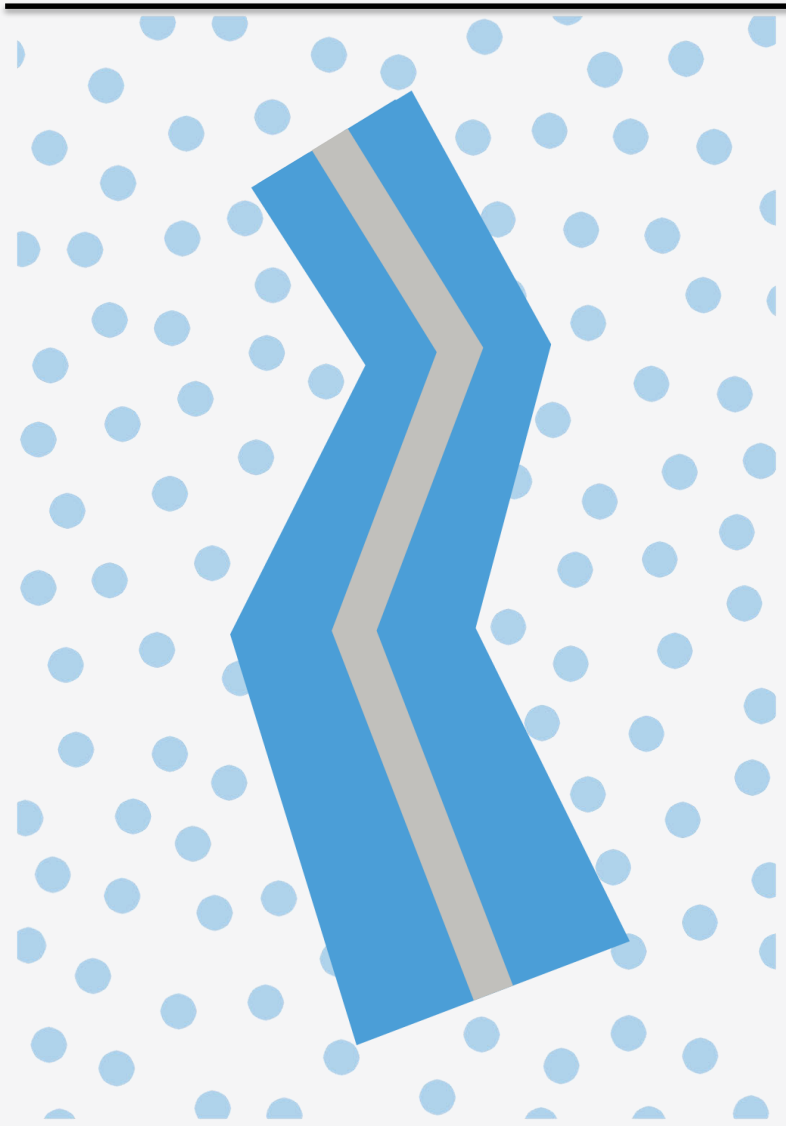
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Capturing Reduced-Liquid



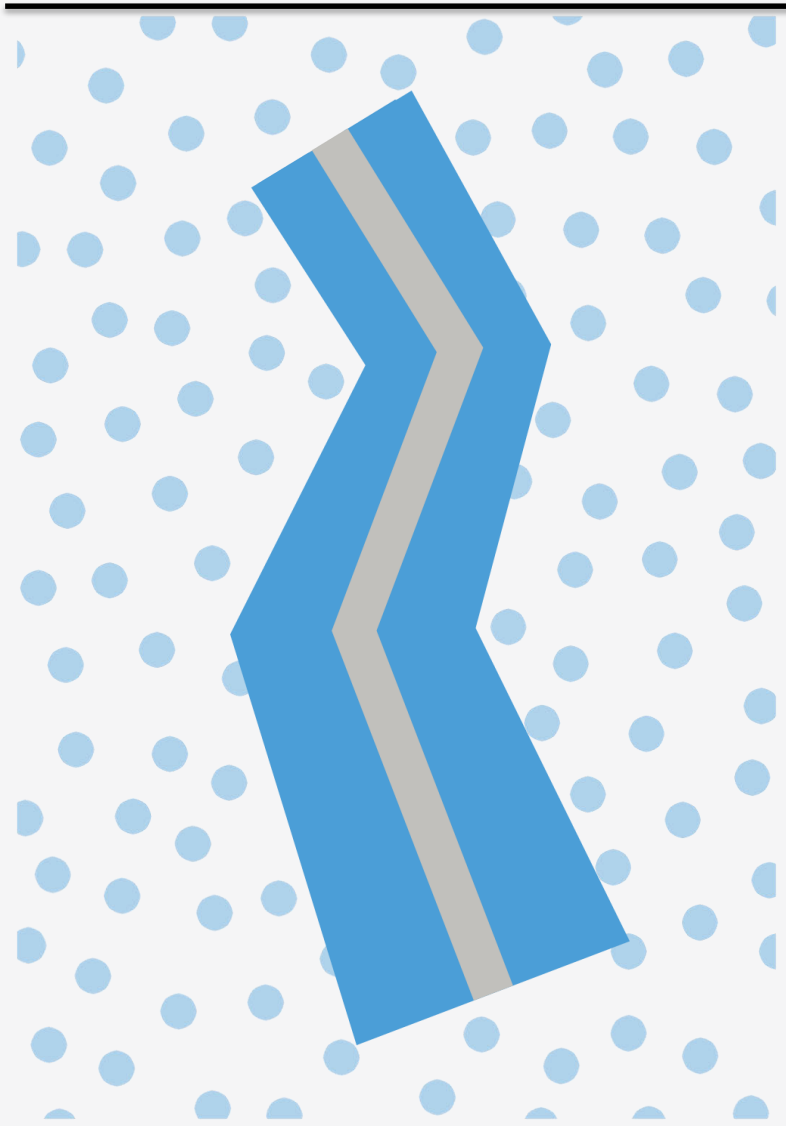
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Capturing Reduced-Liquid



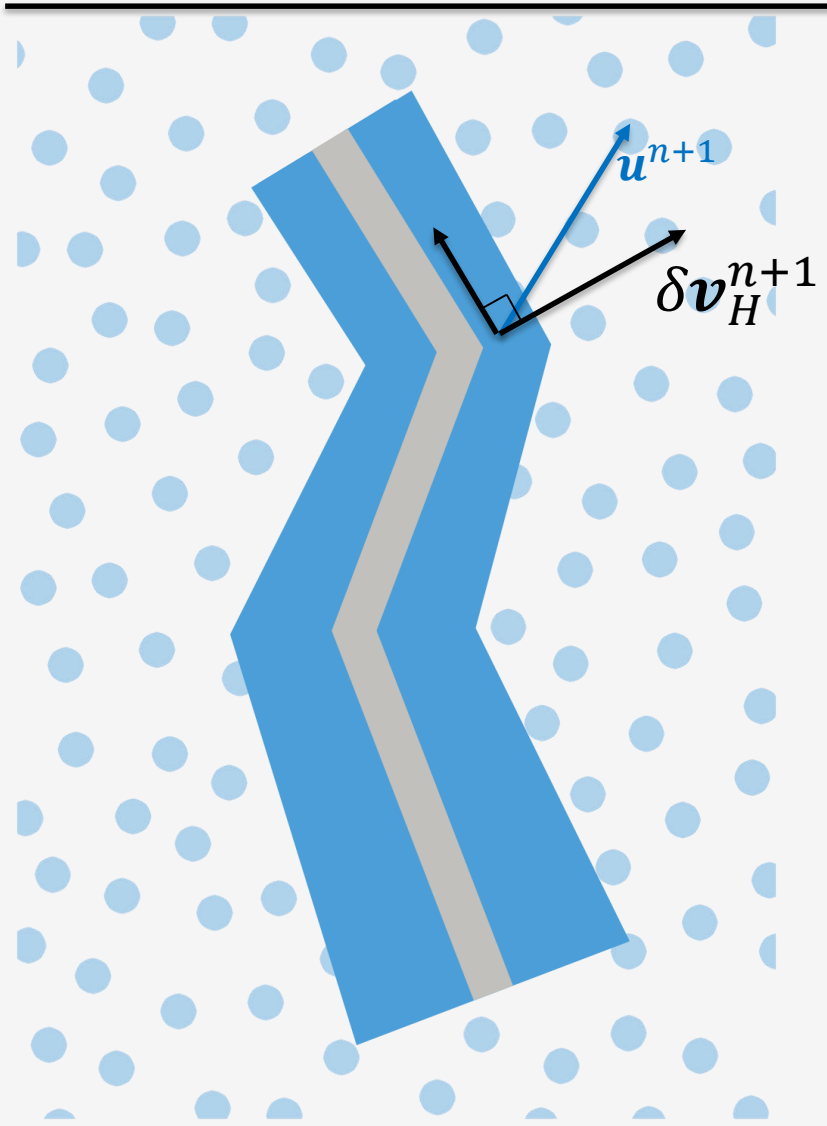
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Capturing Reduced-Liquid



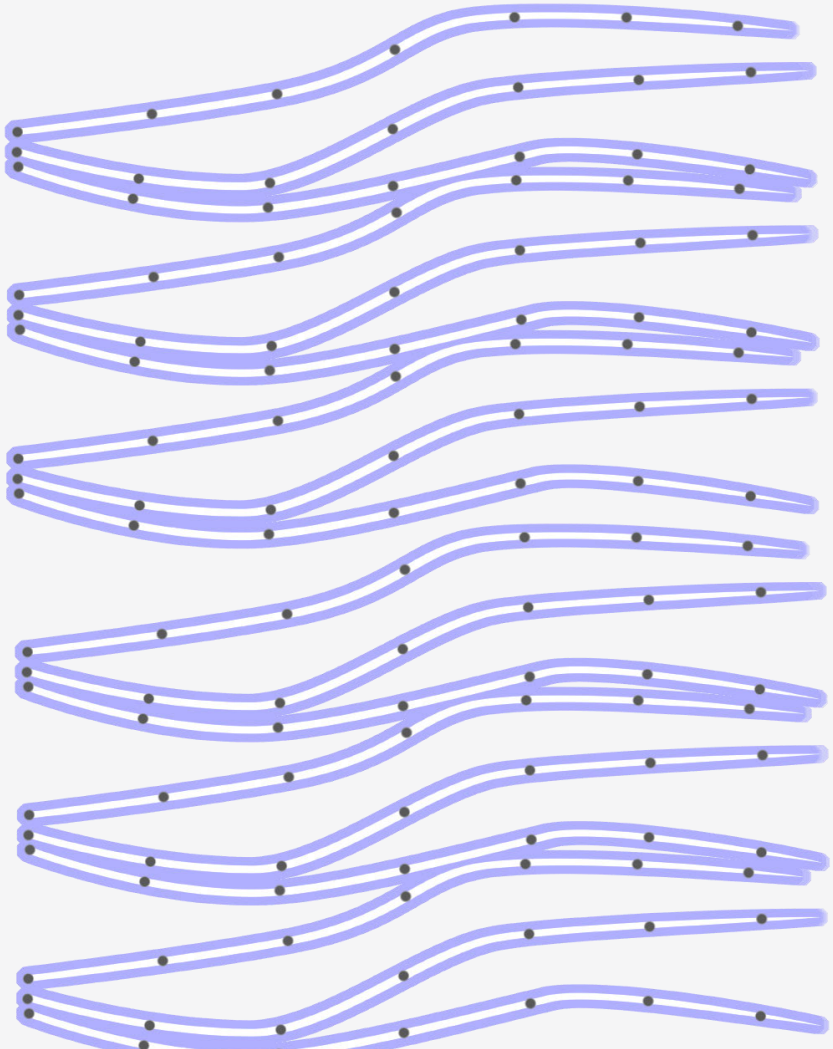
New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

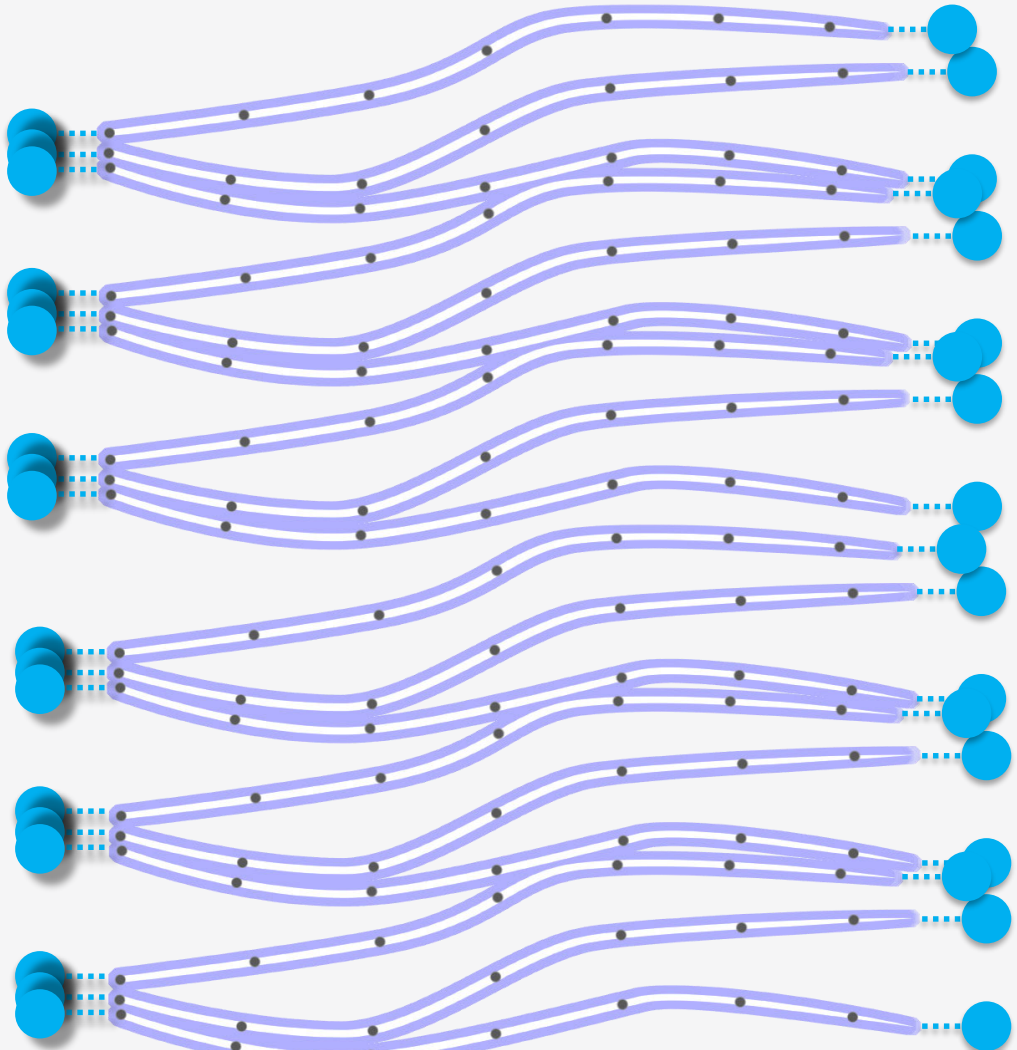
New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Dripping of Reduced-Liquid

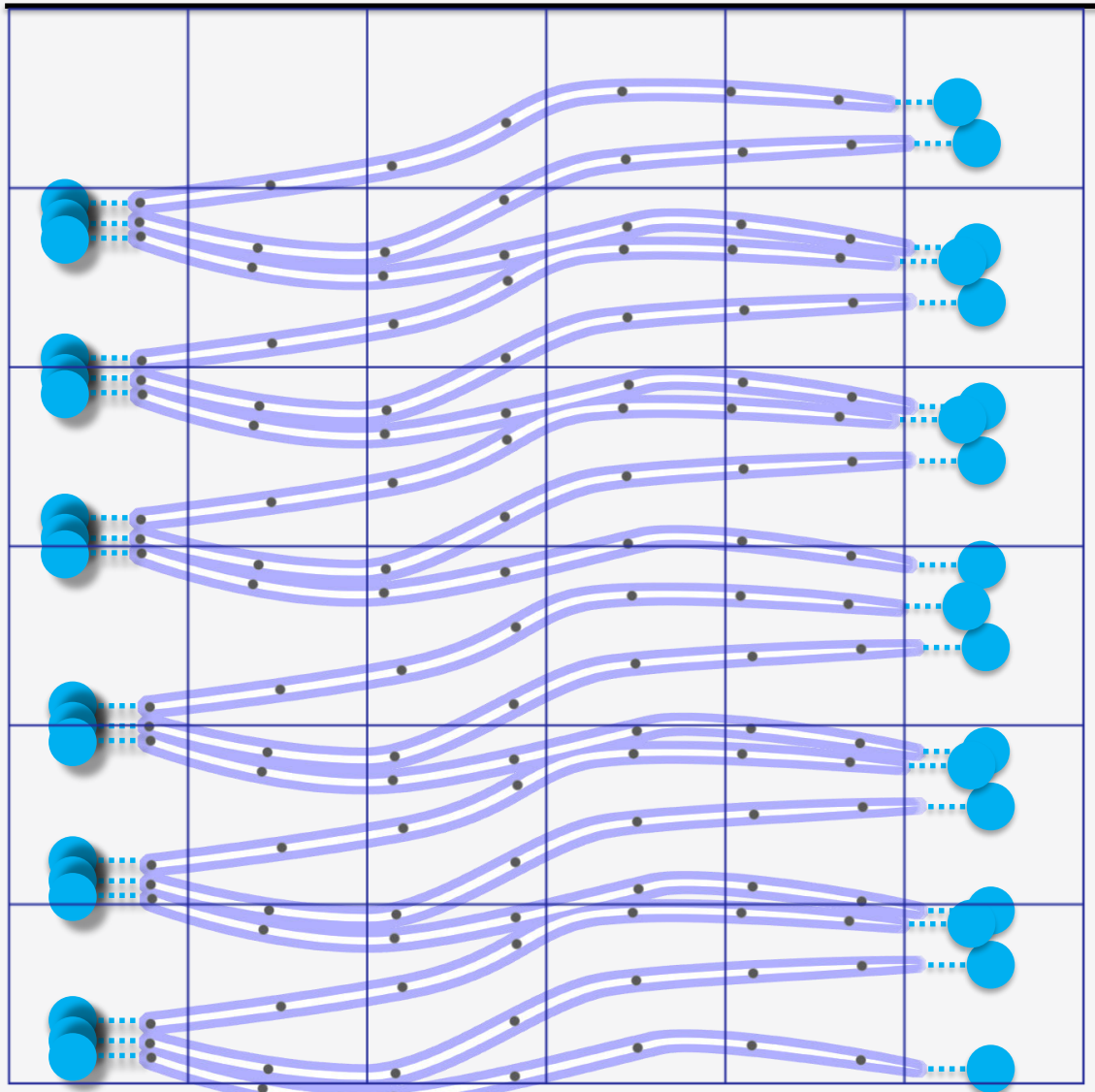


Dripping of Reduced-Liquid

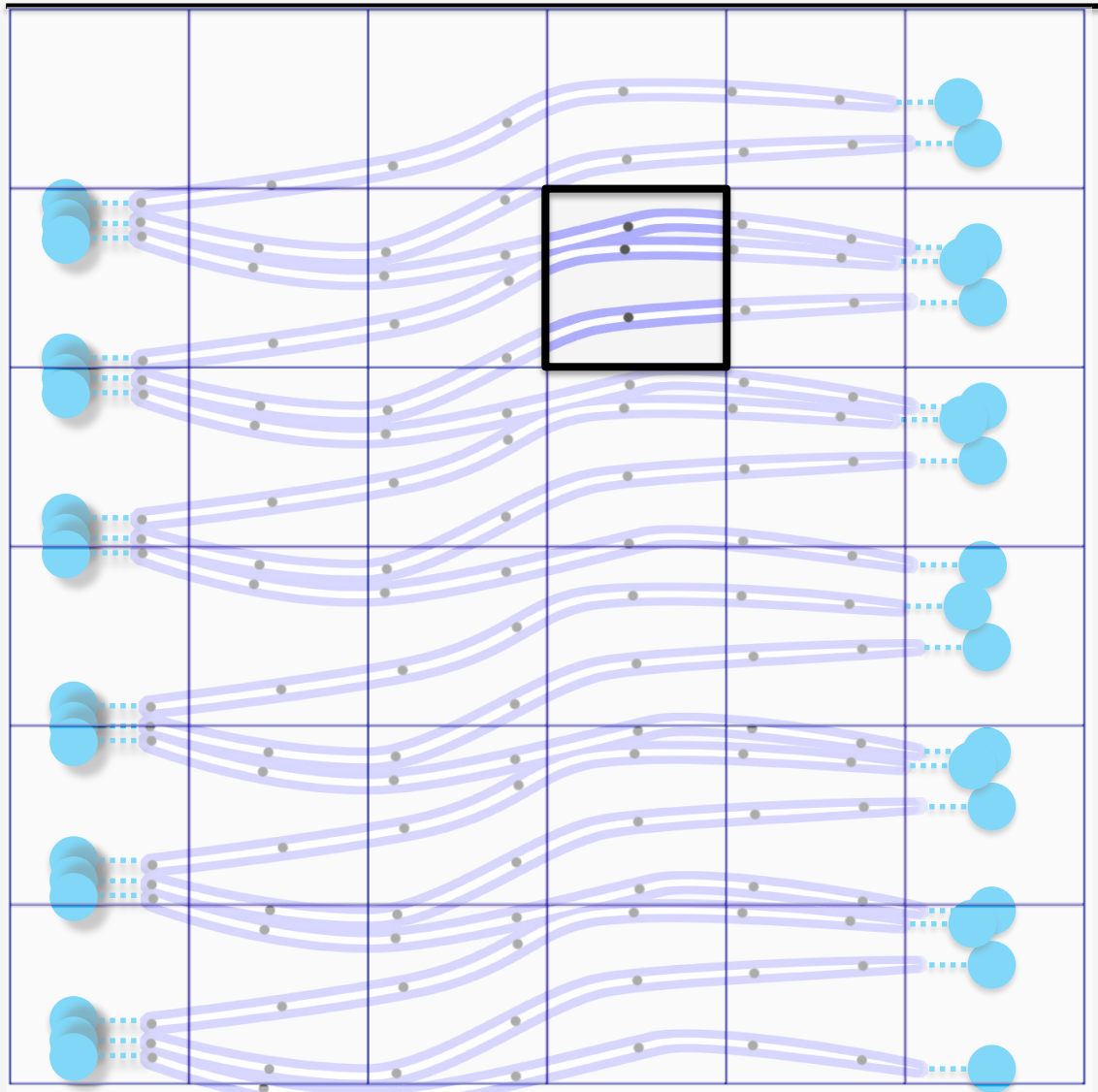


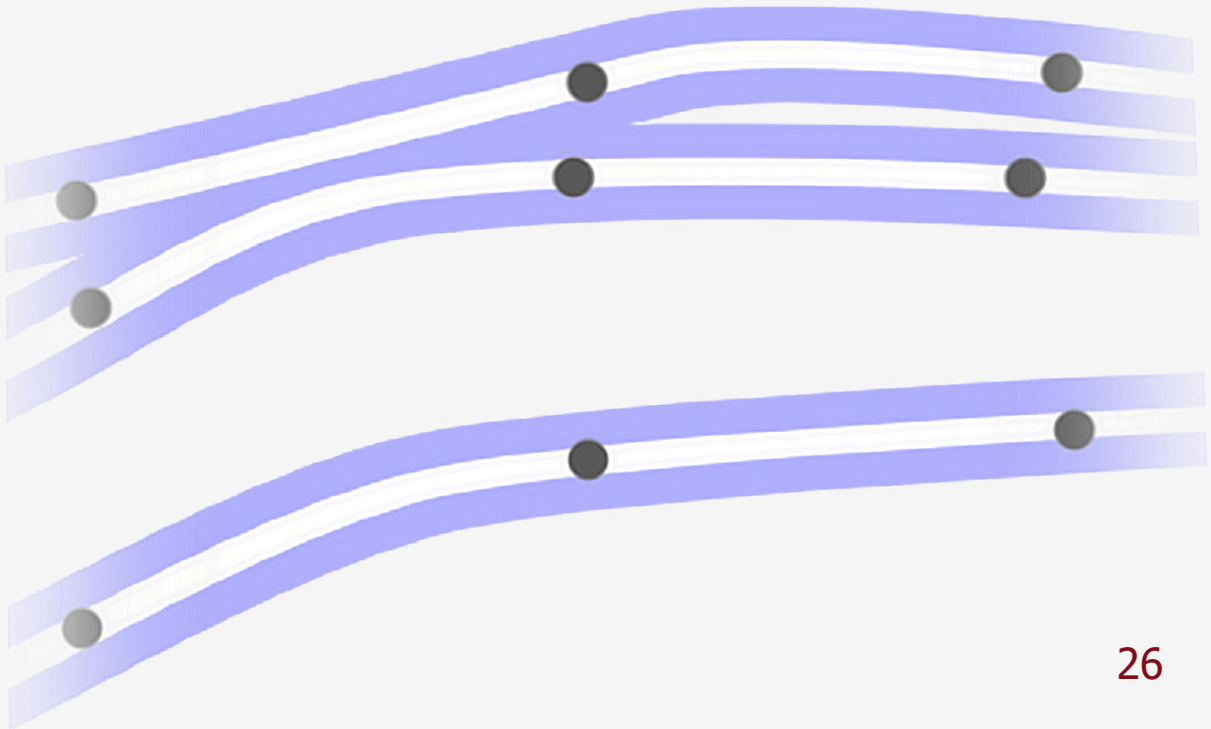
$$V_R = -\pi \int_t \int_s \frac{\partial}{\partial t}[(h+r)^2 - r^2]\mathrm{d}s\mathrm{d}t$$

Dripping of Reduced-Liquid

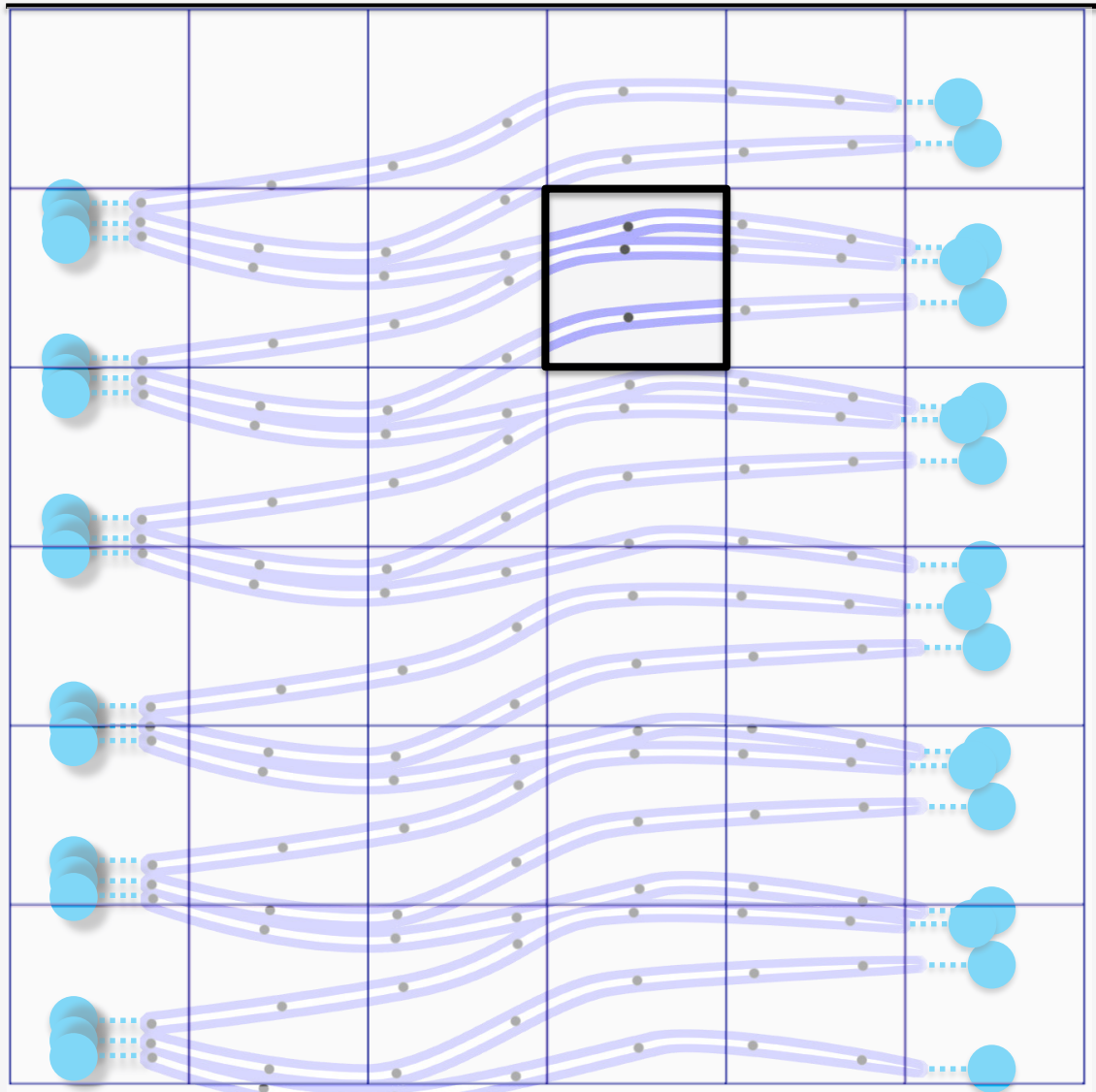


Dripping of Reduced-Liquid





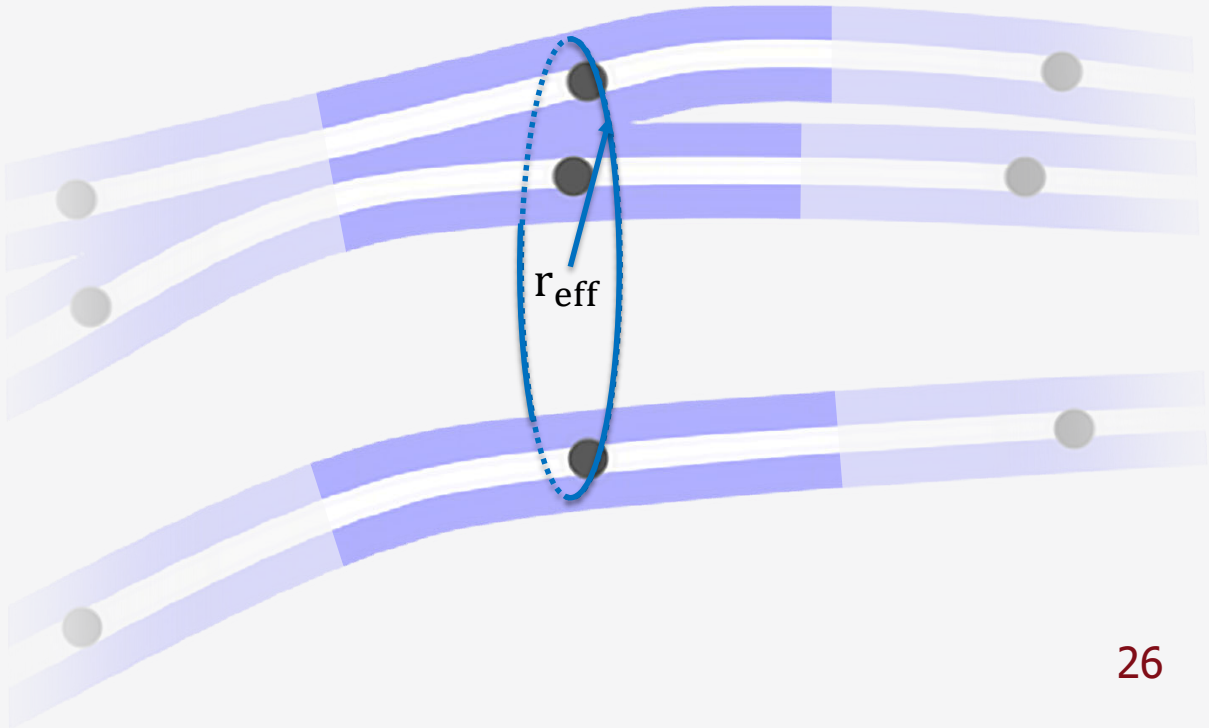
Dripping of Reduced-Liquid



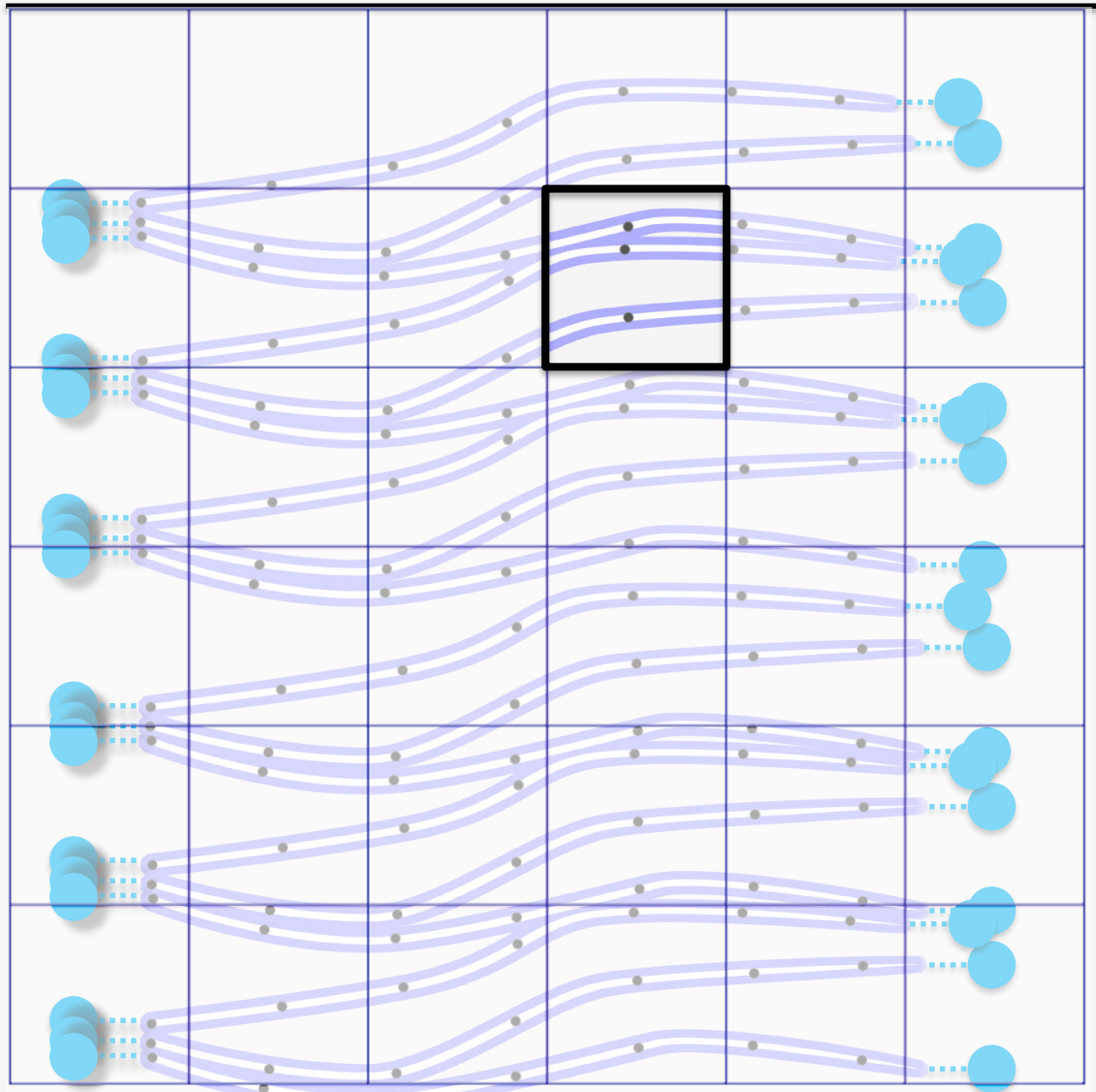
Convert redundant liquid

$$\text{if } r_{\text{eff}} > r_{\max} = \left(\frac{3r\sigma\sqrt{N}}{\rho_L a_{\hat{n}}}\right)^{\frac{1}{3}}$$

[Lorenceau et al. 2004]



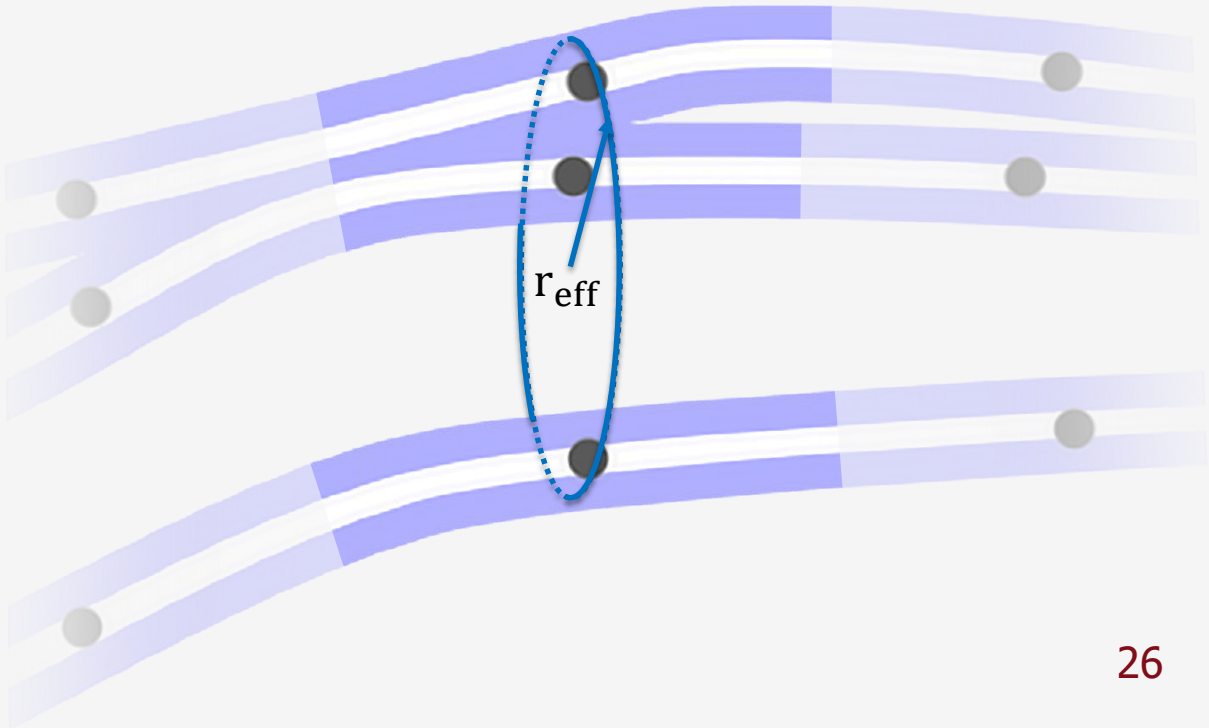
Dripping of Reduced-Liquid



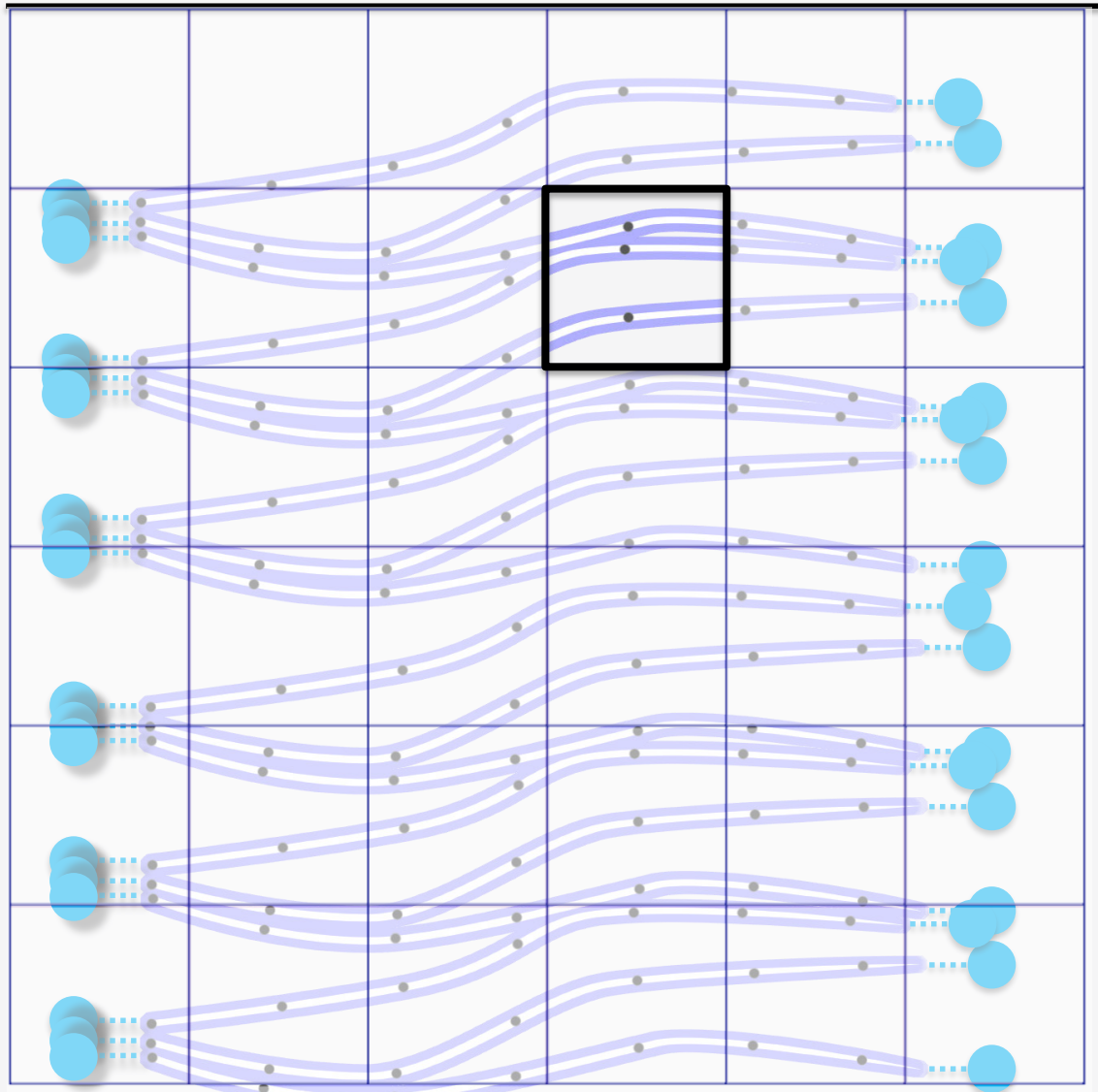
Convert redundant liquid

if $r_{\text{eff}} > \boxed{r_{\max}} = \left(\frac{3r\sigma\sqrt{N}}{\rho_L a_{\hat{n}}}\right)^{\frac{1}{3}}$

[Lorenceau et al. 2004]



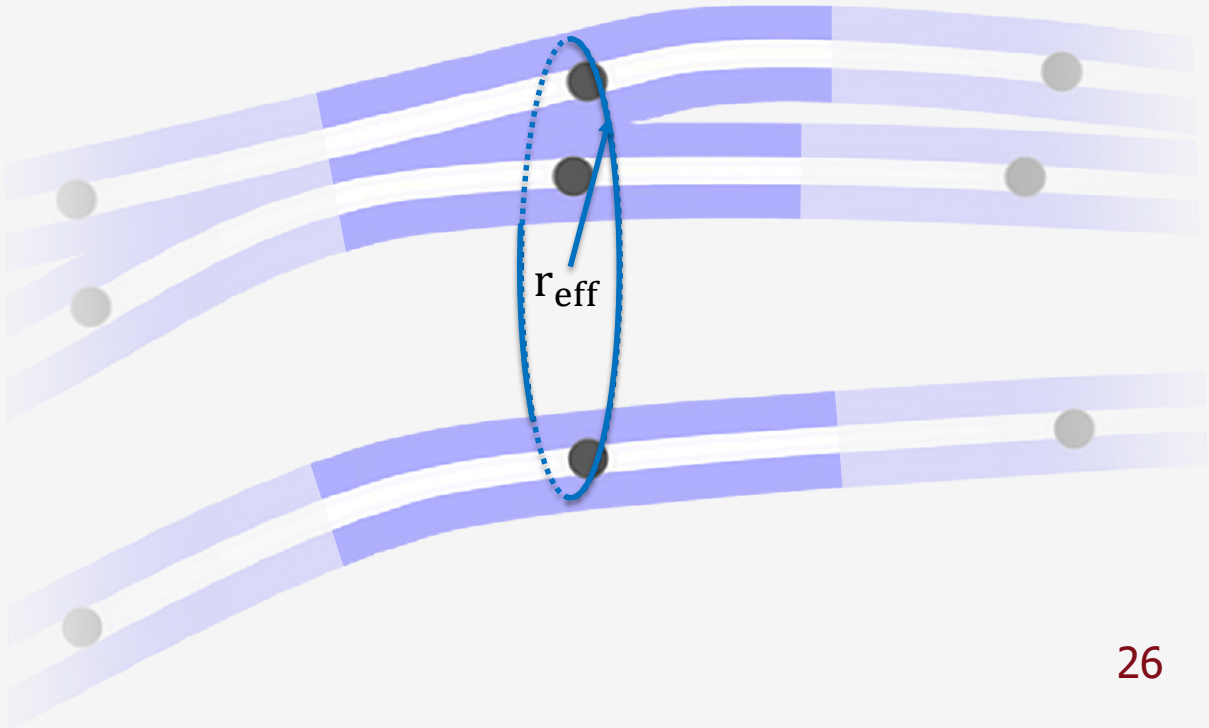
Dripping of Reduced-Liquid



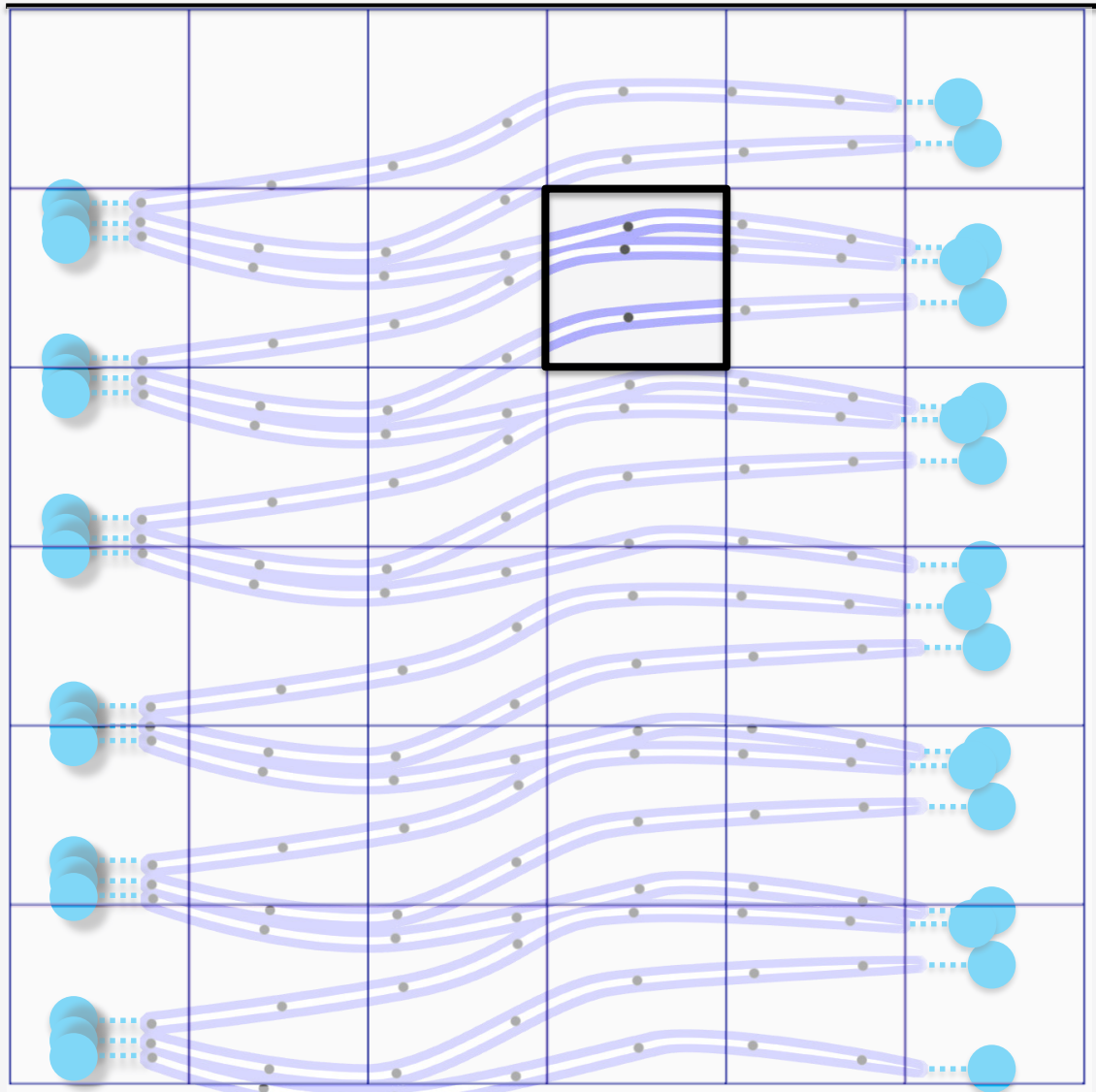
Convert redundant liquid

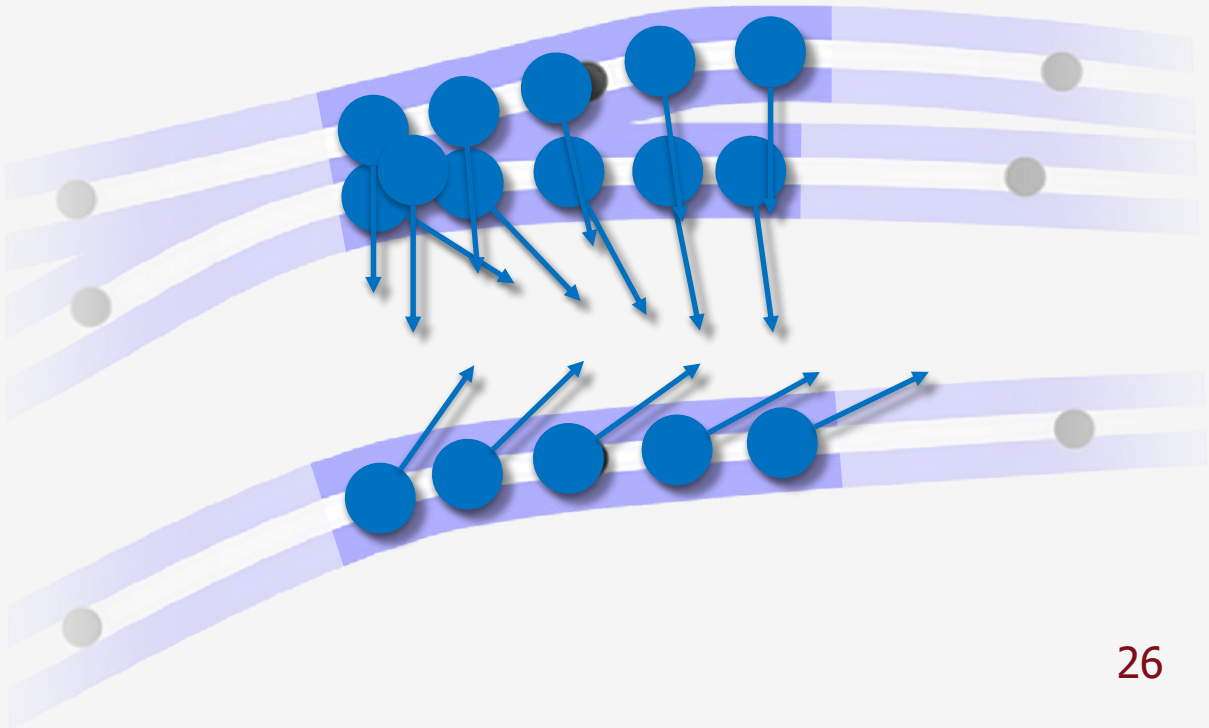
$$\text{if } r_{\text{eff}} > r_{\max} = \left(\frac{3r\sigma\sqrt{N}}{\rho_L a_{\hat{n}}}\right)^{\frac{1}{3}}$$

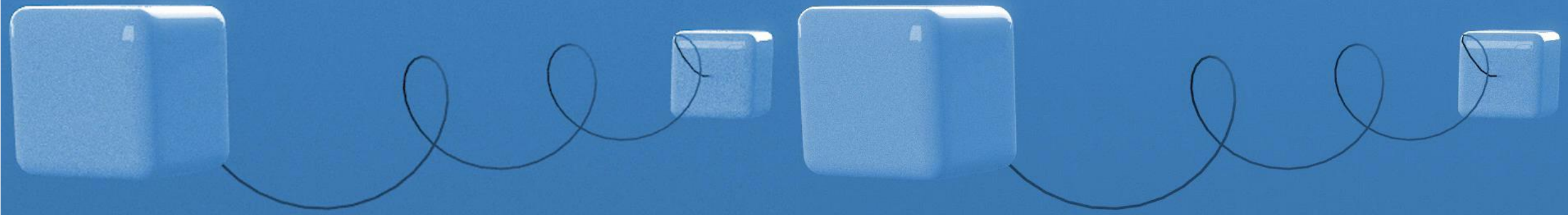
[Lorenceau et al. 2004]



Dripping of Reduced-Liquid



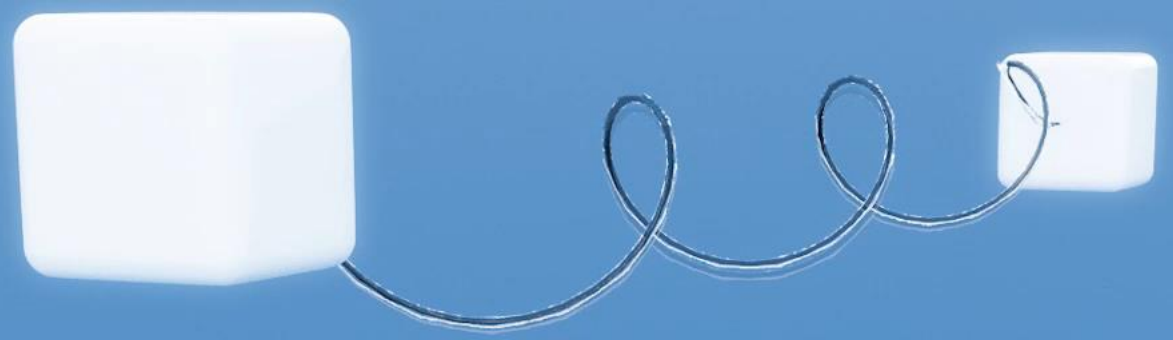




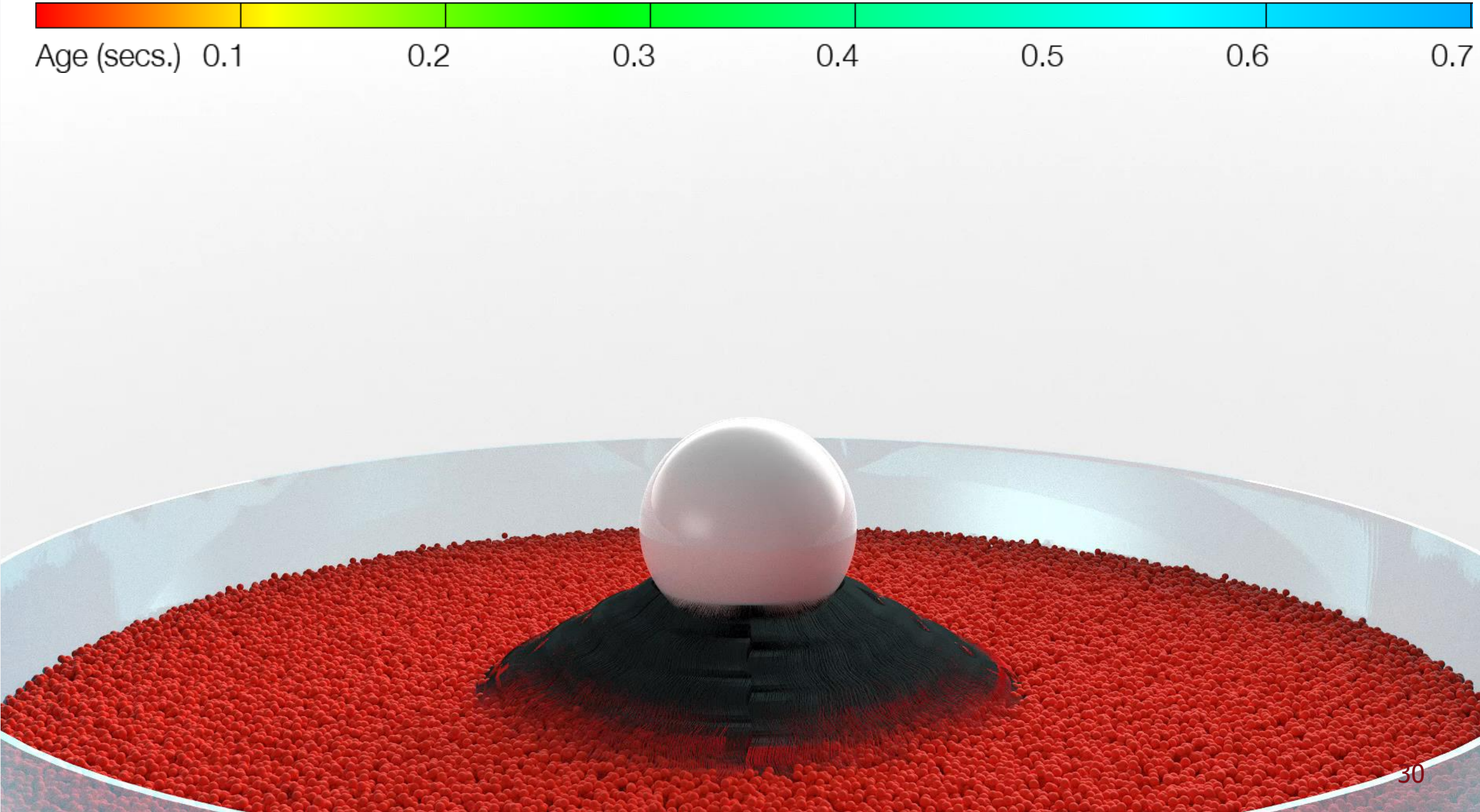
Capture OFF

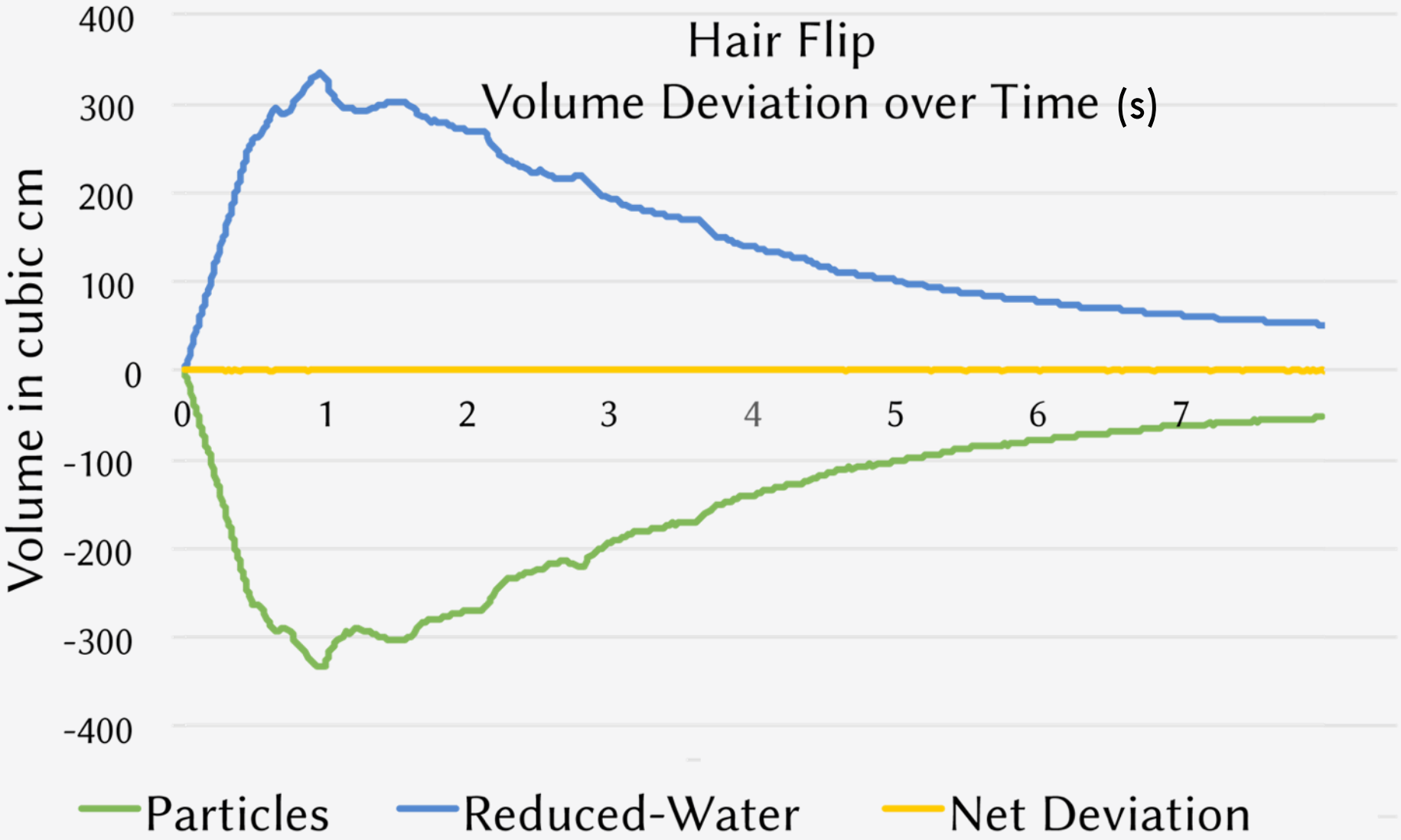
Capture ON

Dripping OFF



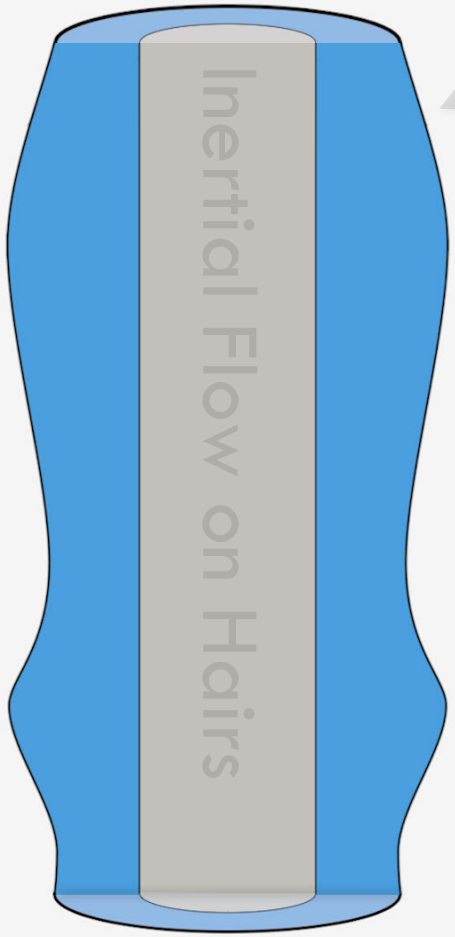
Dripping ON


Age (secs.) 0.1 0.2 0.3 0.4 0.5 0.6 0.7


Hair Flip
Volume Deviation over Time (s)
Volume in cubic cm
400
300
200
100
0
-100
-200
-300
-400
0
1
2
3
4
5
6
7
Particles
Reduced-Water
Net Deviation

Cohesion

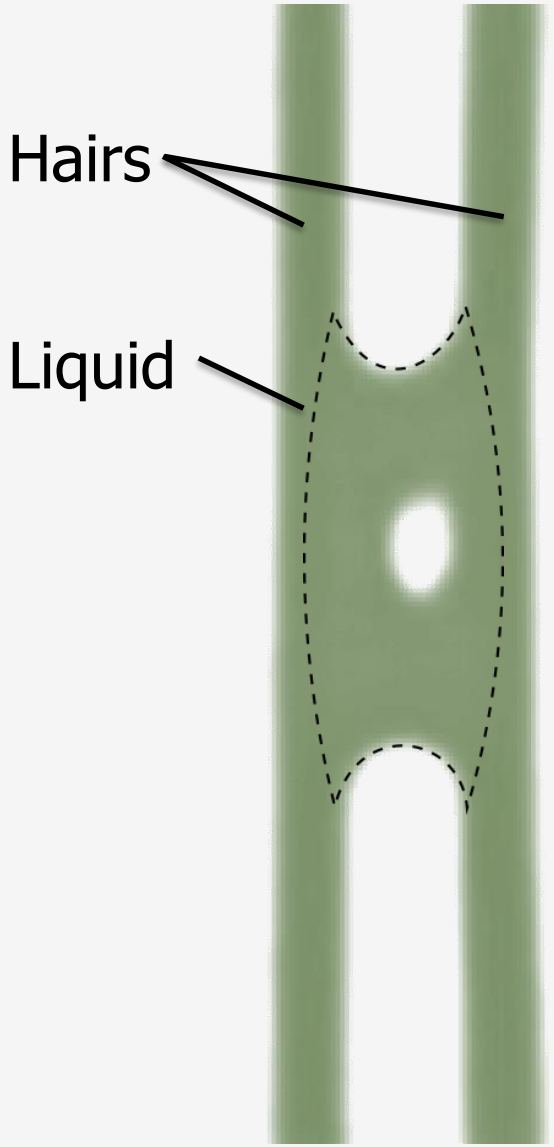
Collision



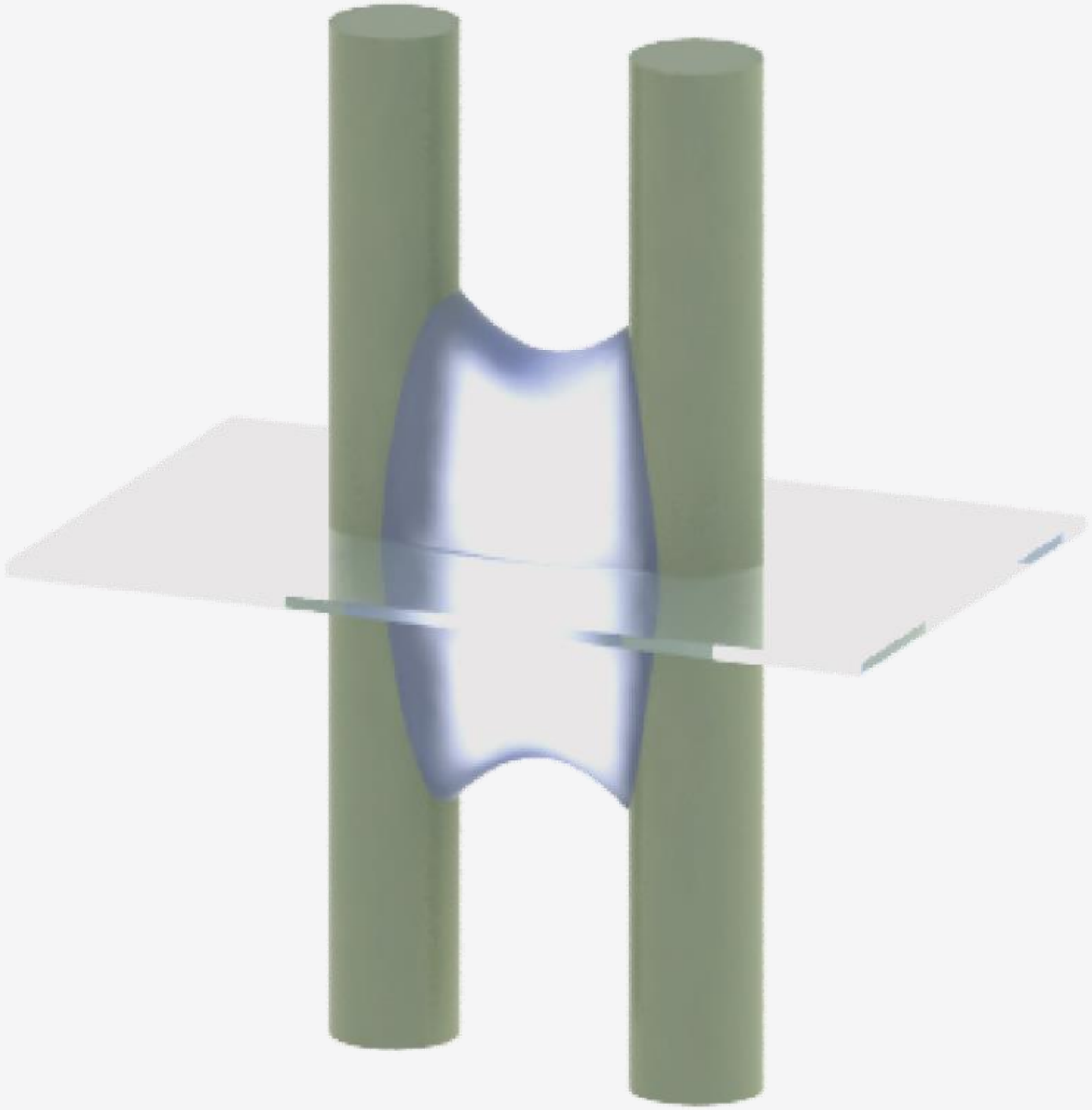
Two-way Coupling

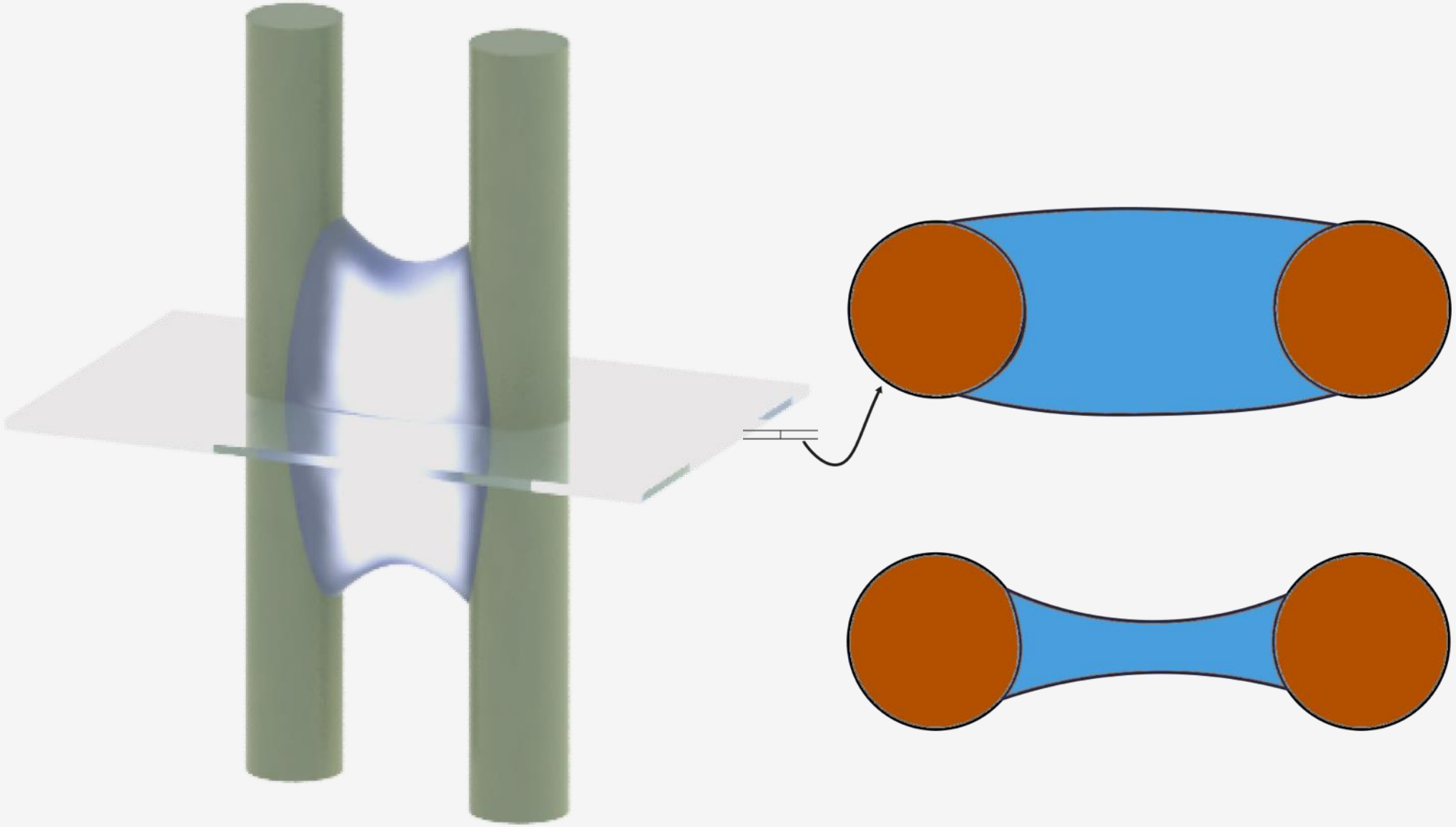
Dripping

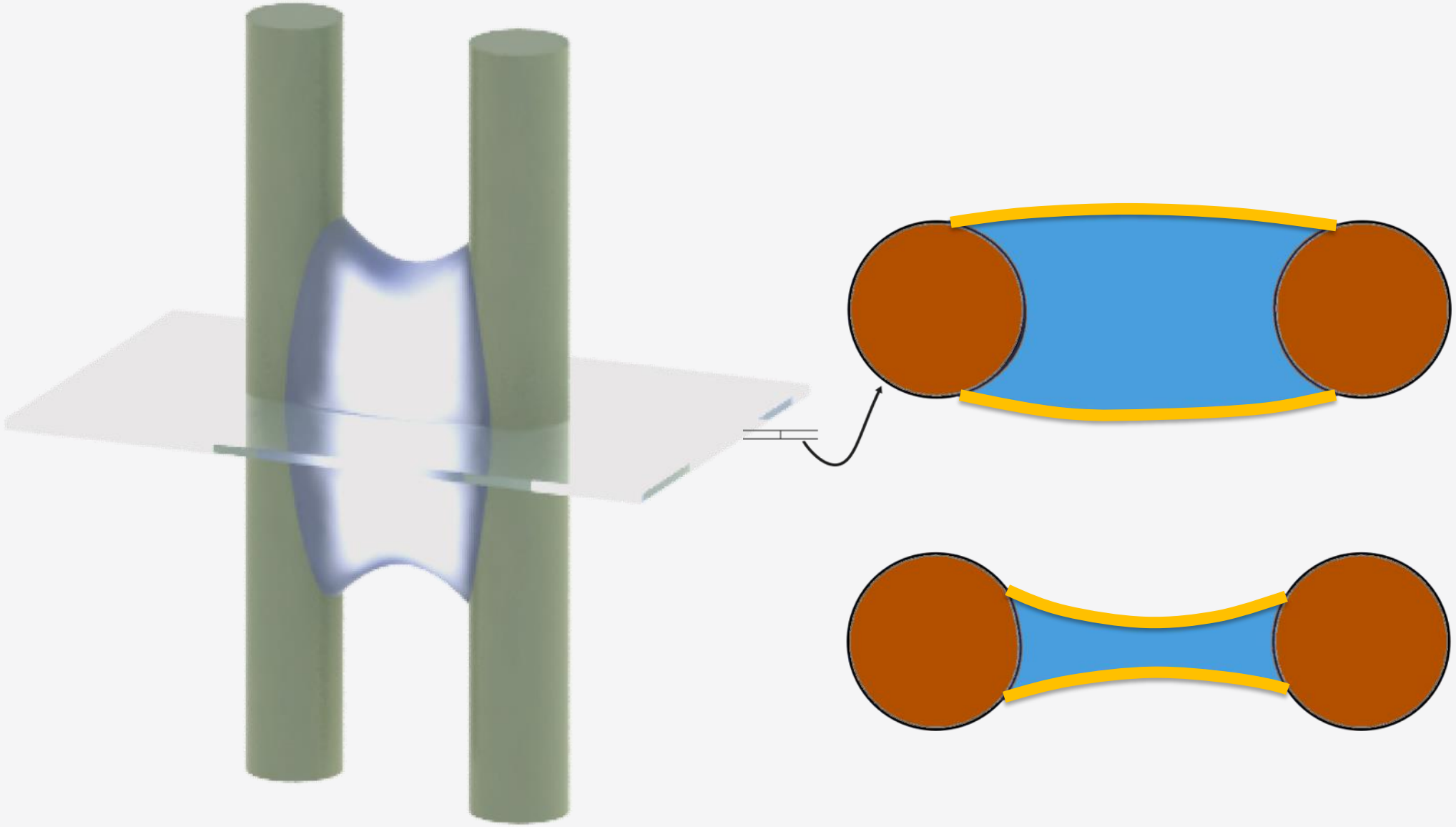
Capturing

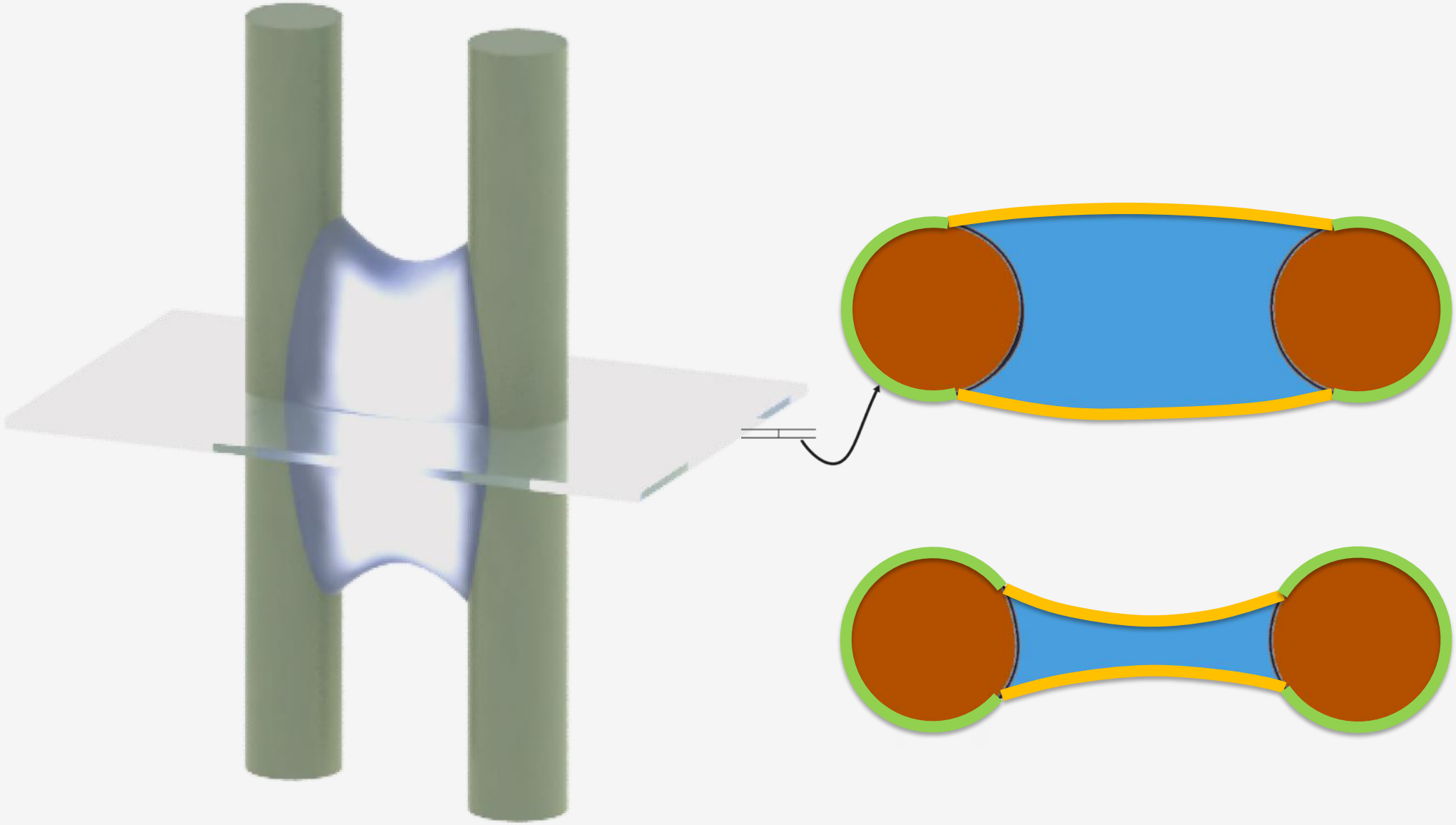


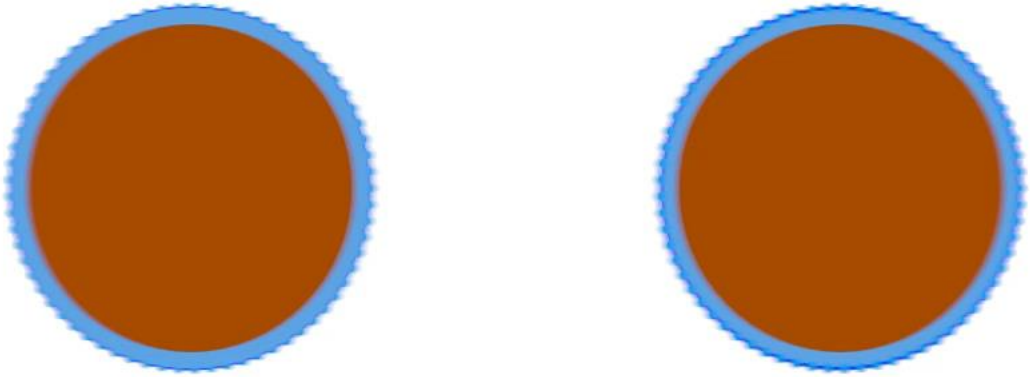
Real Experiment [Wang et al. 2014]

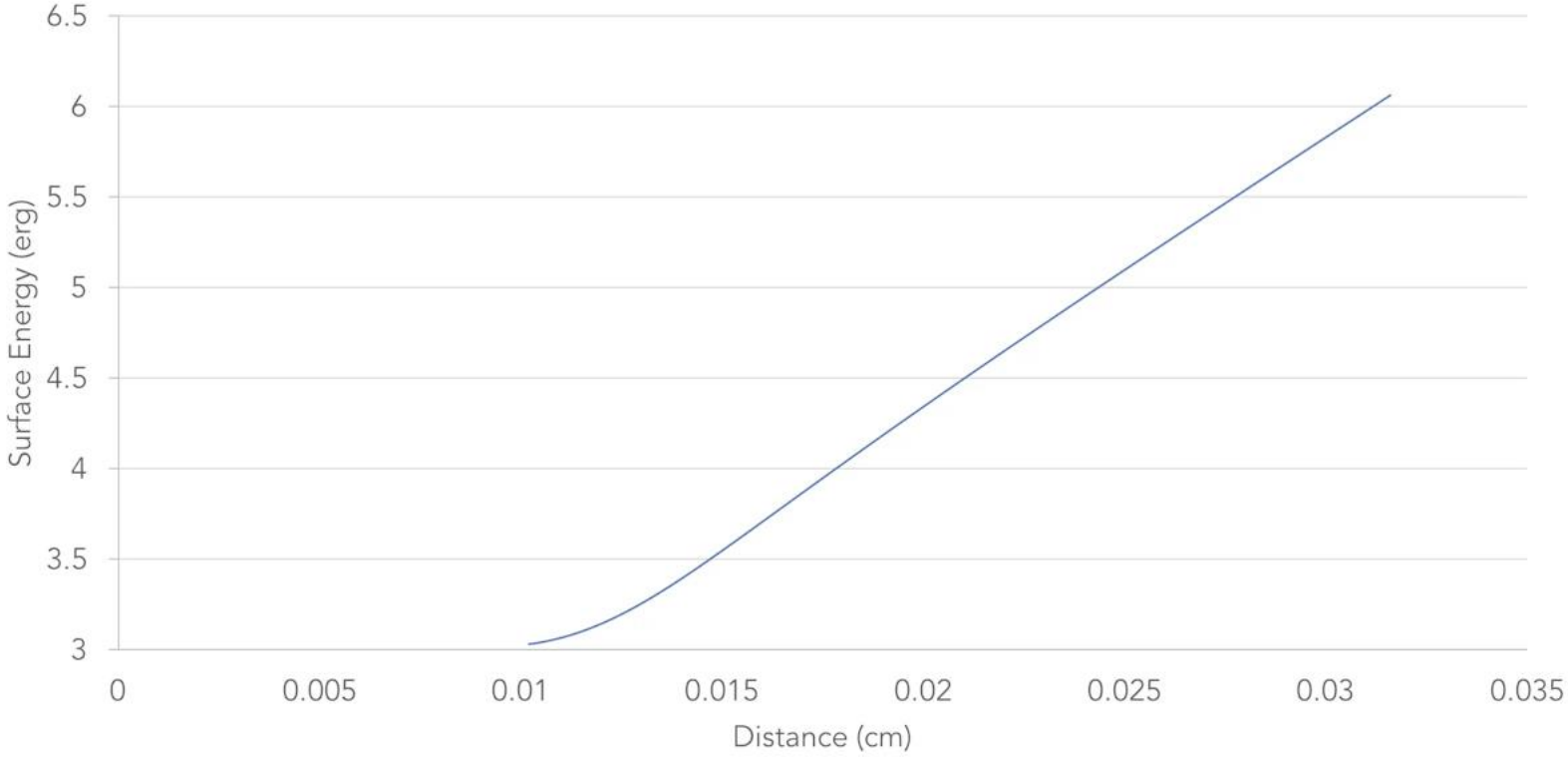


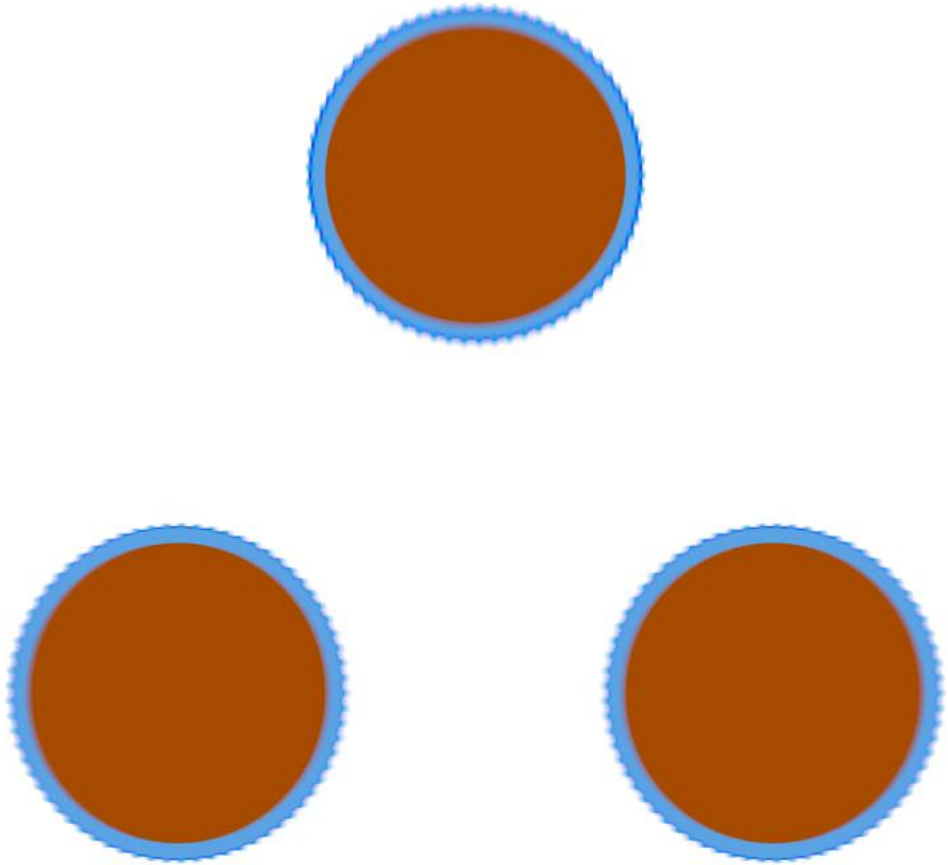


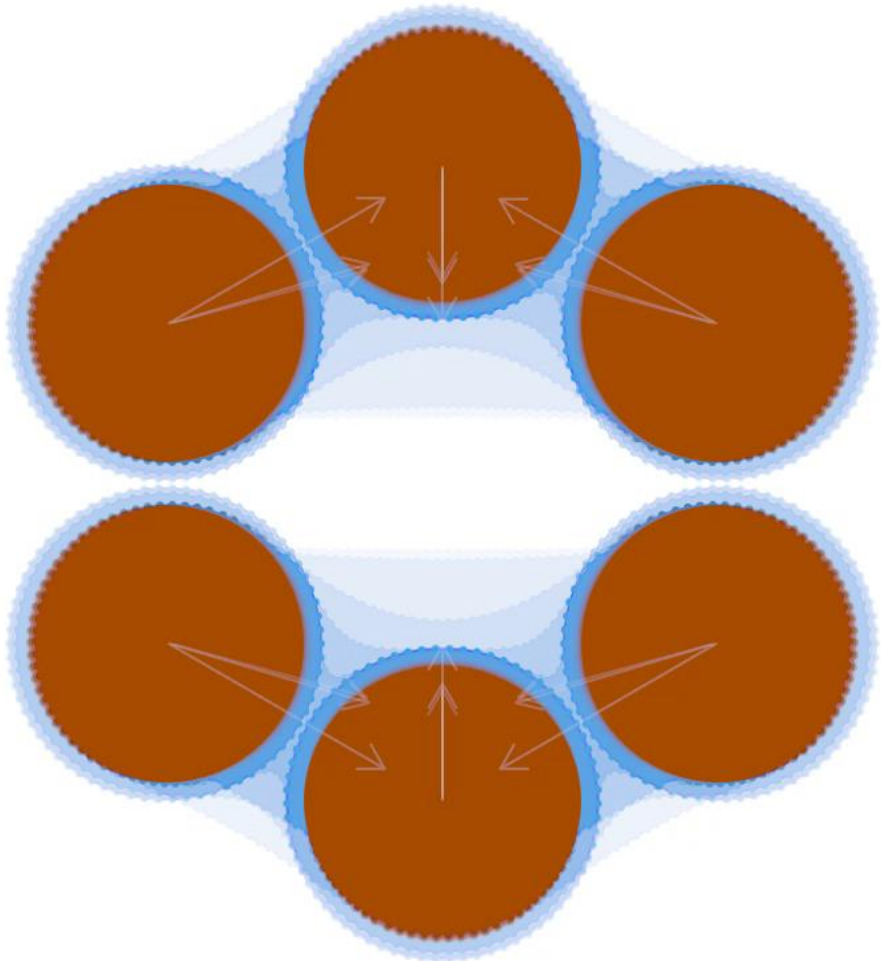


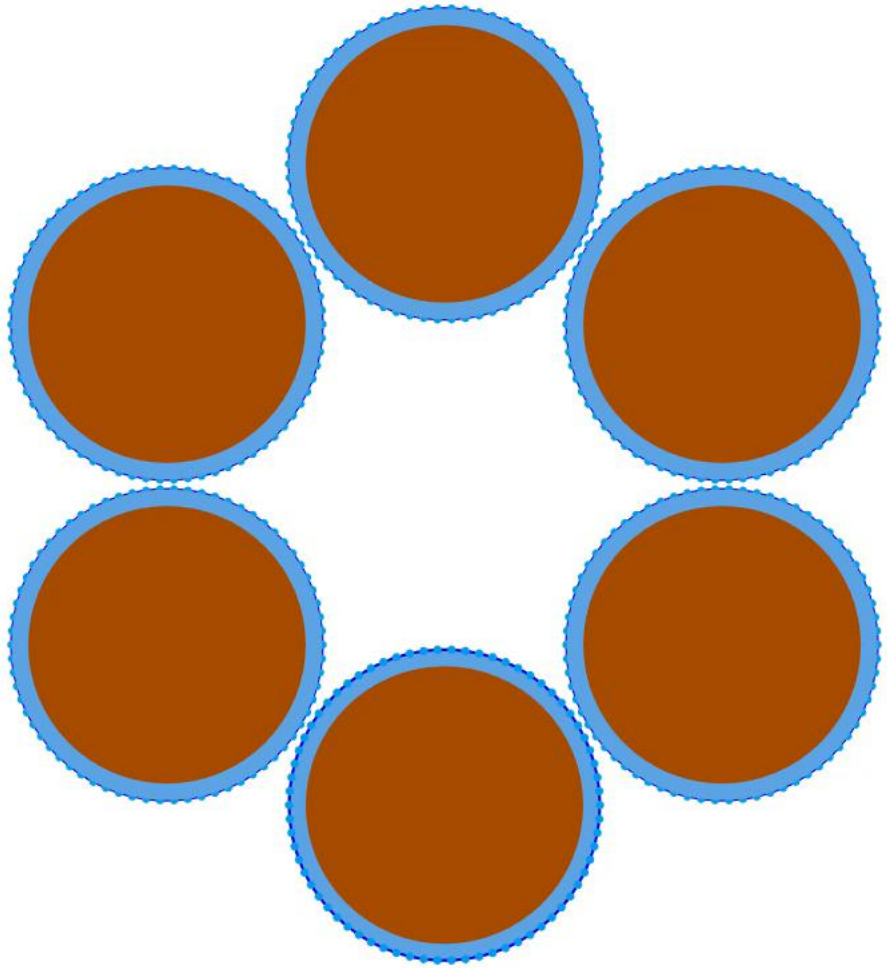




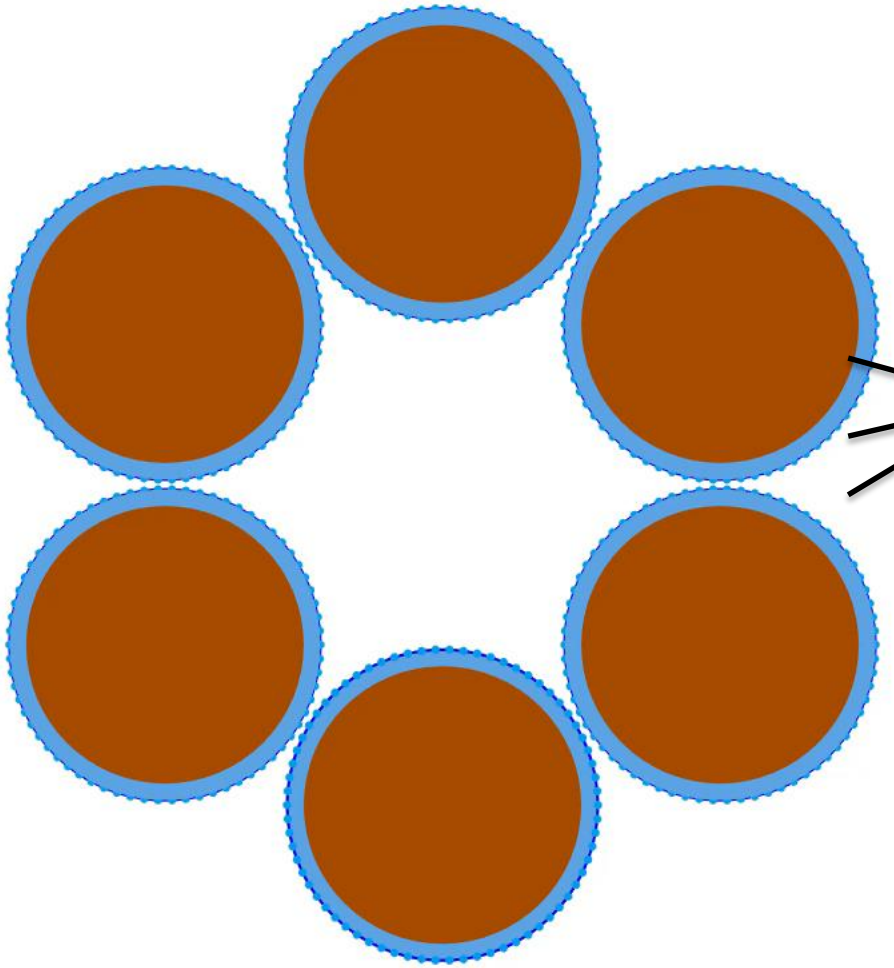

6.5
6
5.5
5
4.5
4
3.5
3
Surface Energy (erg)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
Distance (cm)



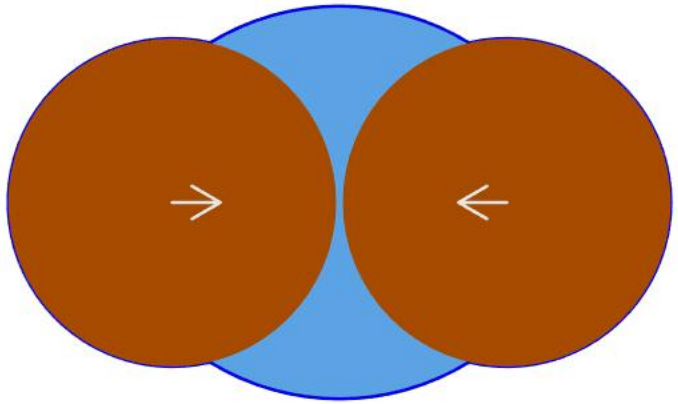




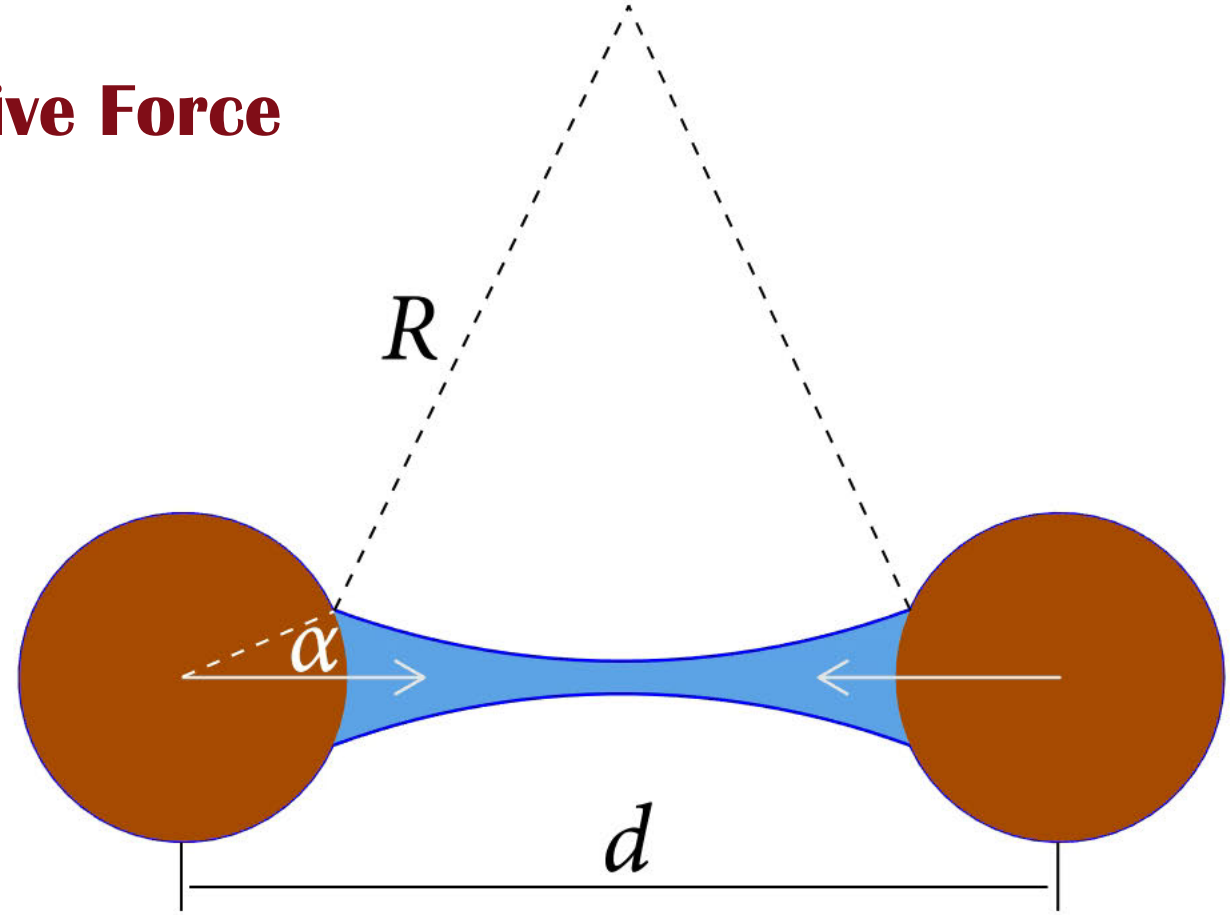
Too Costly for Practical Applications



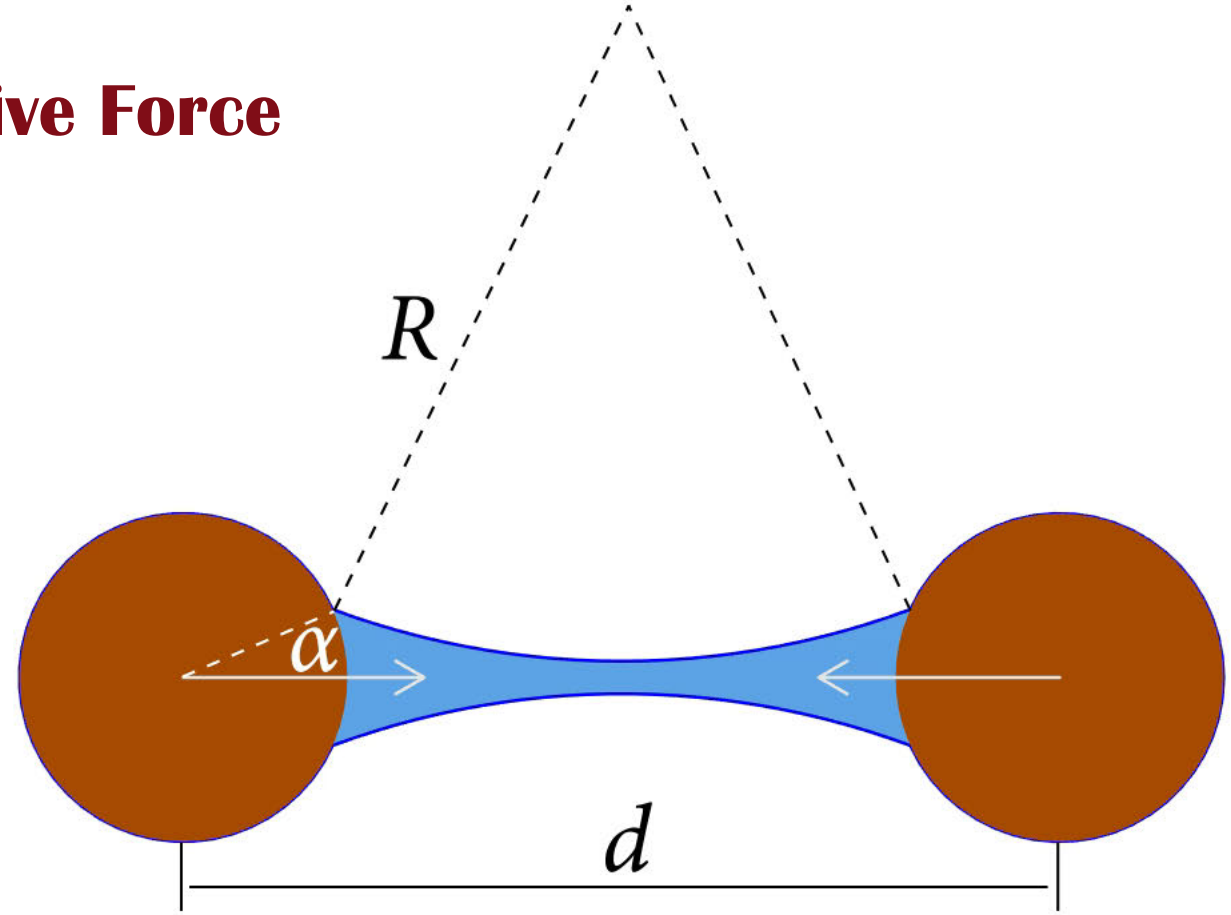
Analytical Model



Compute Cohesive Force

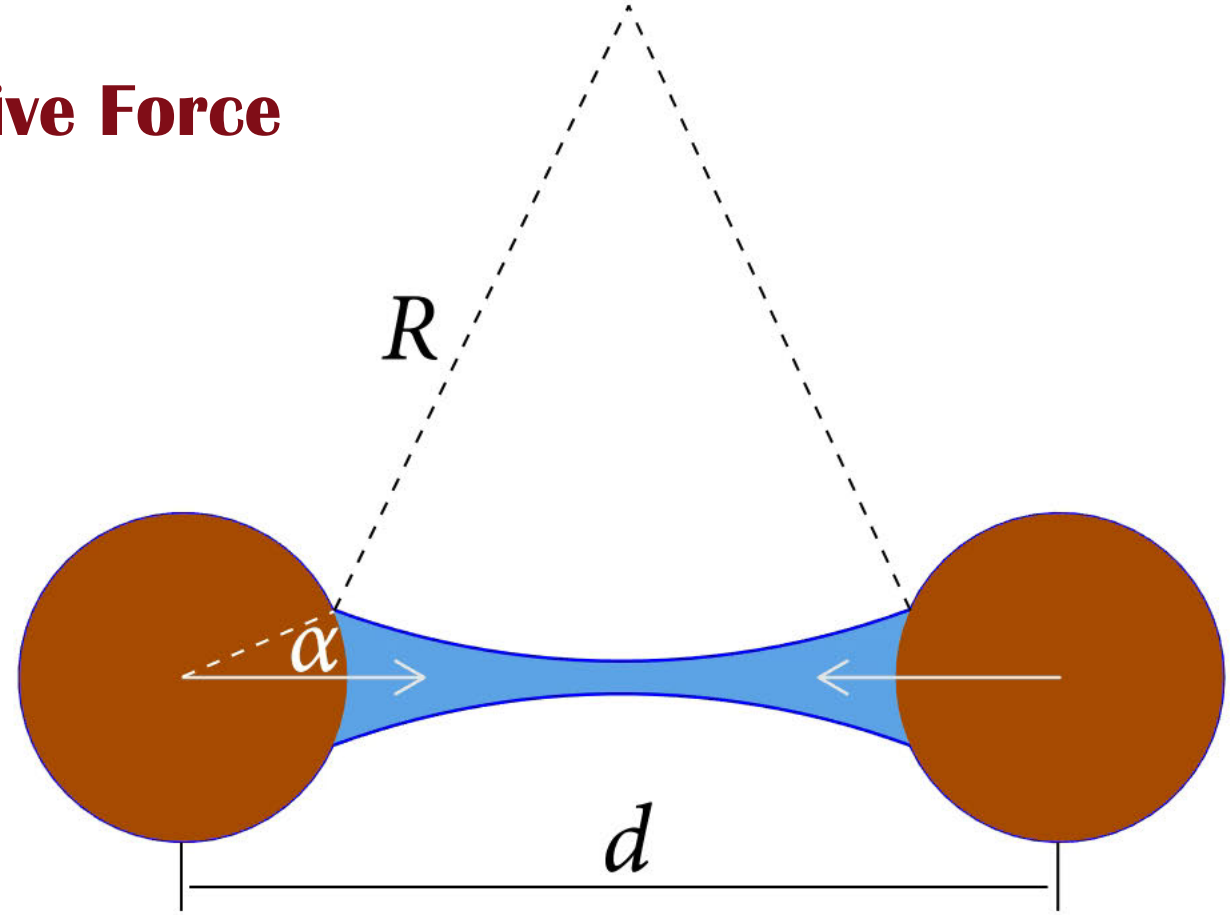


Compute Cohesive Force



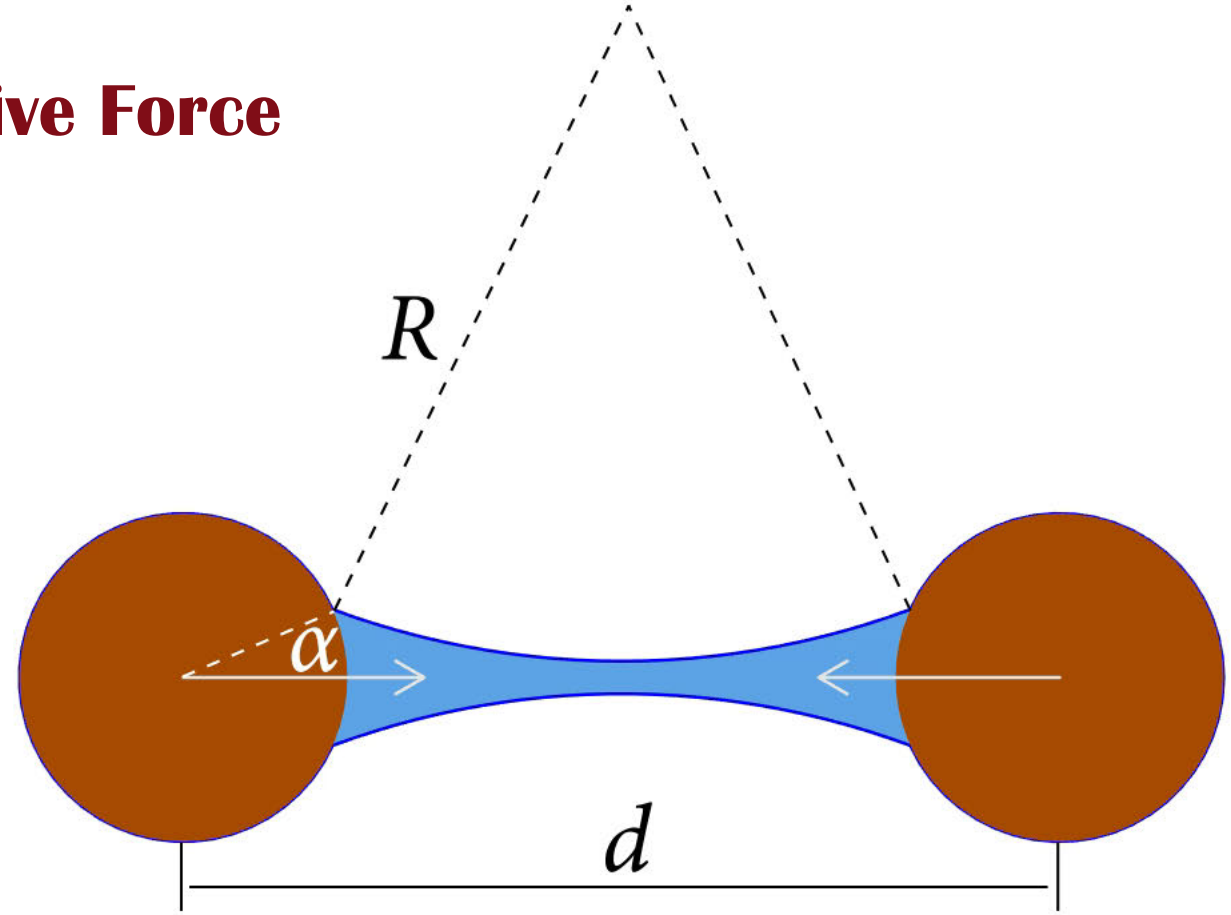
$$f\mathrm{d}s = -\frac{\partial \mathrm{d}E_s}{\partial d} = -\left(\frac{\partial \mathrm{d}E_s}{\partial R}\cdot\frac{\partial R}{\partial d} + \sum_{i=1,2}\frac{\partial \mathrm{d}E_s}{\partial \alpha_i}\cdot\frac{\partial \alpha_i}{\partial d}\right)$$

Compute Cohesive Force



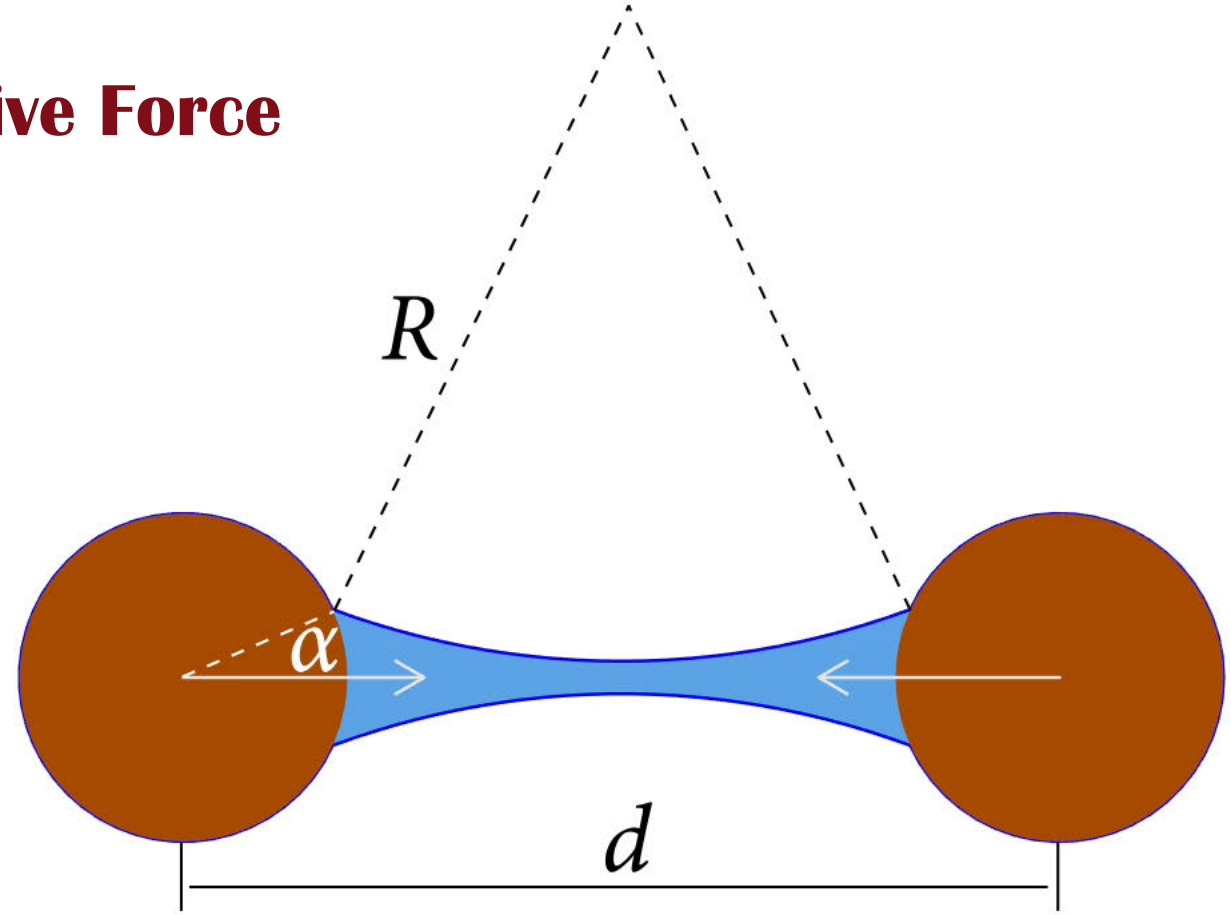
$$f\mathrm{d}s = -\frac{\partial \mathrm{d}E_s}{\partial d} = -\left(\frac{\partial \mathrm{d}E_s}{\partial R}\cdot\frac{\partial R}{\partial d} + \sum_{i=1,2}\frac{\partial \mathrm{d}E_s}{\partial \alpha_i}\cdot\frac{\partial \alpha_i}{\partial d}\right)$$

Compute Cohesive Force



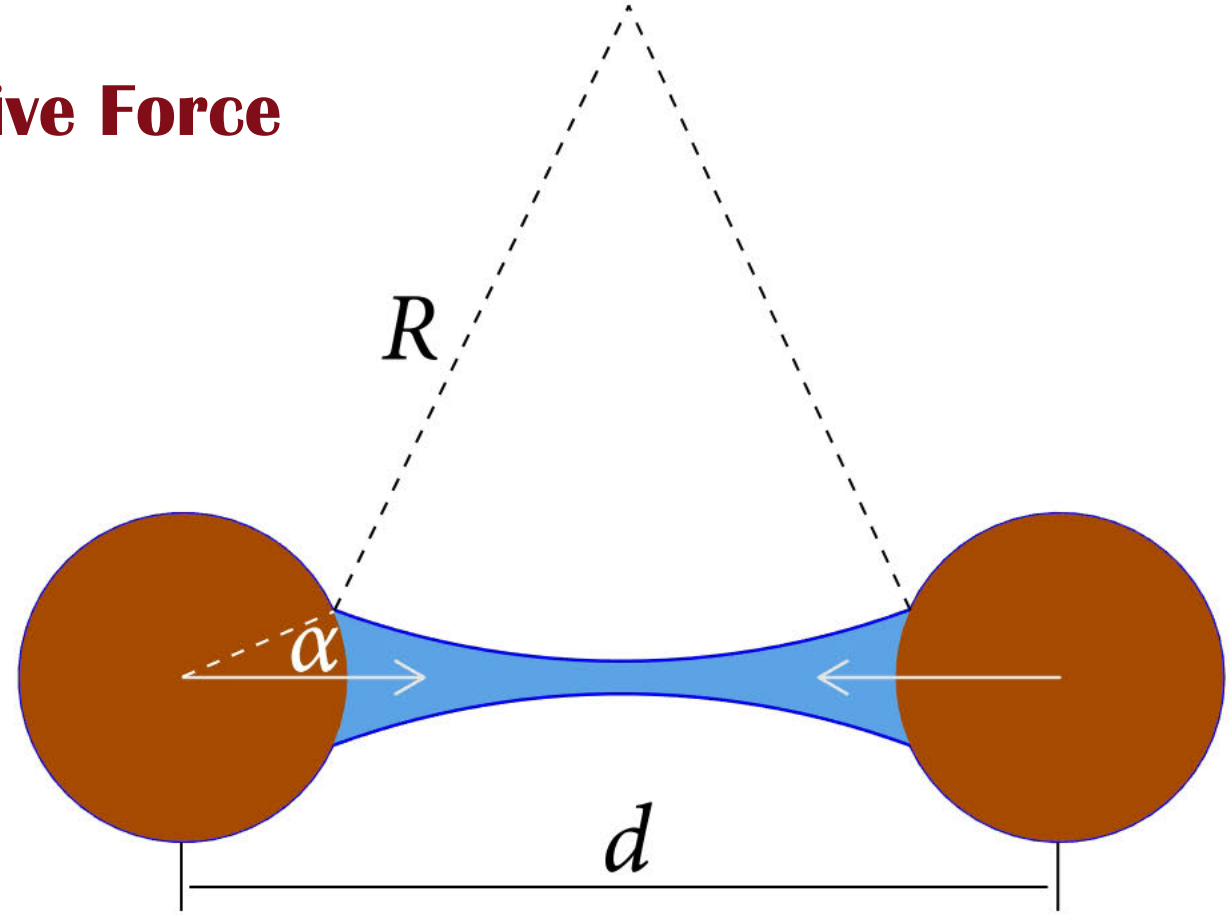
$$f\mathrm{d}s = -\frac{\partial \mathrm{d}E_s}{\partial d} = -\left(\frac{\partial \mathrm{d}E_s}{\partial R}\cdot\boxed{\frac{\partial R}{\partial d}} + \sum_{i=1,2}\frac{\partial \mathrm{d}E_s}{\partial \alpha_i}\cdot\boxed{\frac{\partial \alpha_i}{\partial d}}\right)$$

Compute Cohesive Force



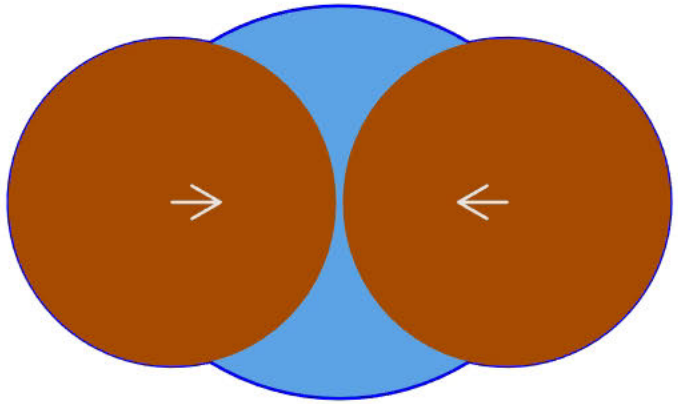
$$f\mathrm{d}s = -\boxed{\frac{\partial \mathrm{d}E_s}{\partial d}} = -\left(\frac{\partial \mathrm{d}E_s}{\partial R}\cdot\frac{\partial R}{\partial d} + \sum_{i=1,2}\frac{\partial \mathrm{d}E_s}{\partial \alpha_i}\cdot\frac{\partial \alpha_i}{\partial d}\right)$$

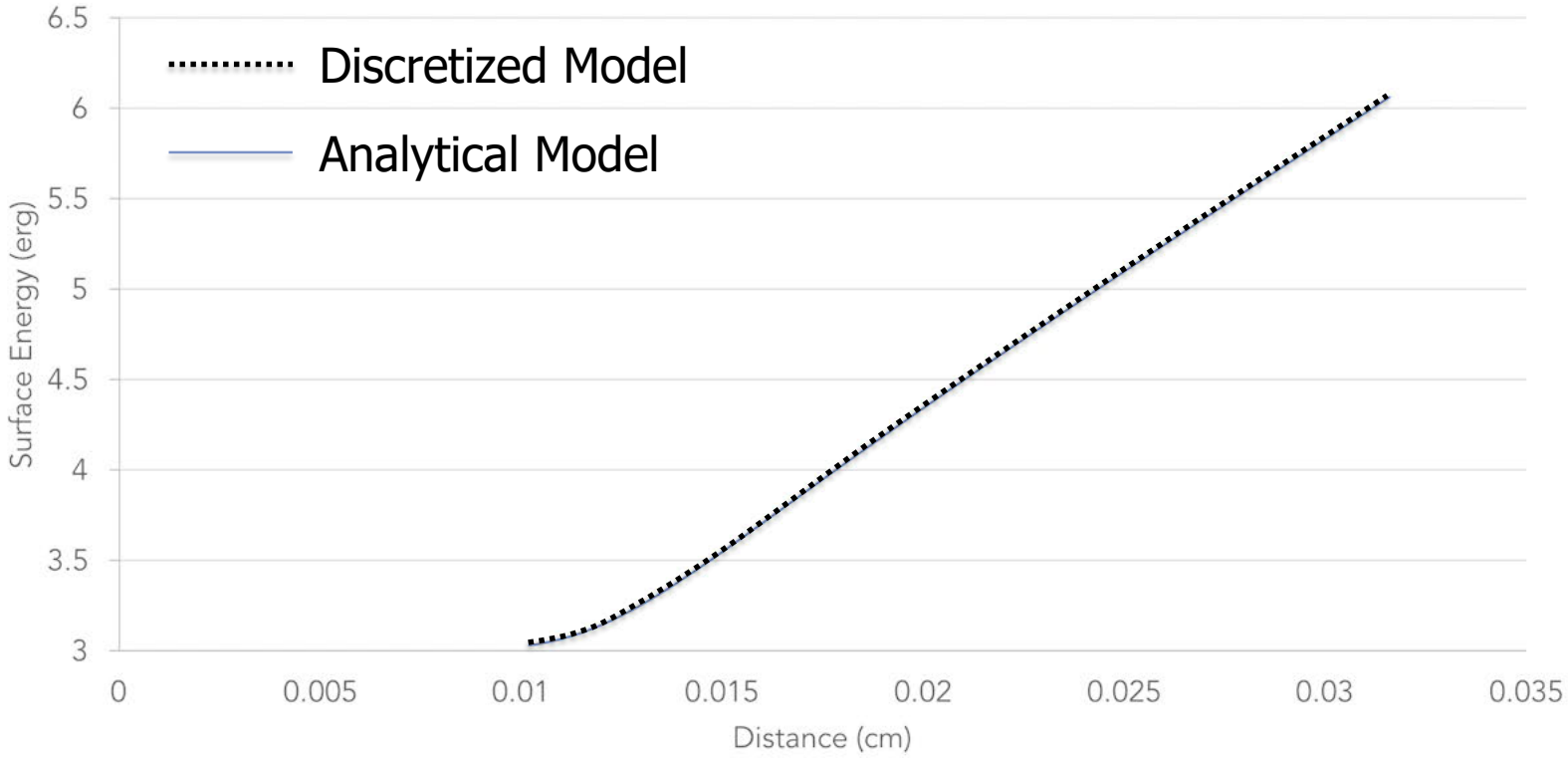
Compute Cohesive Force

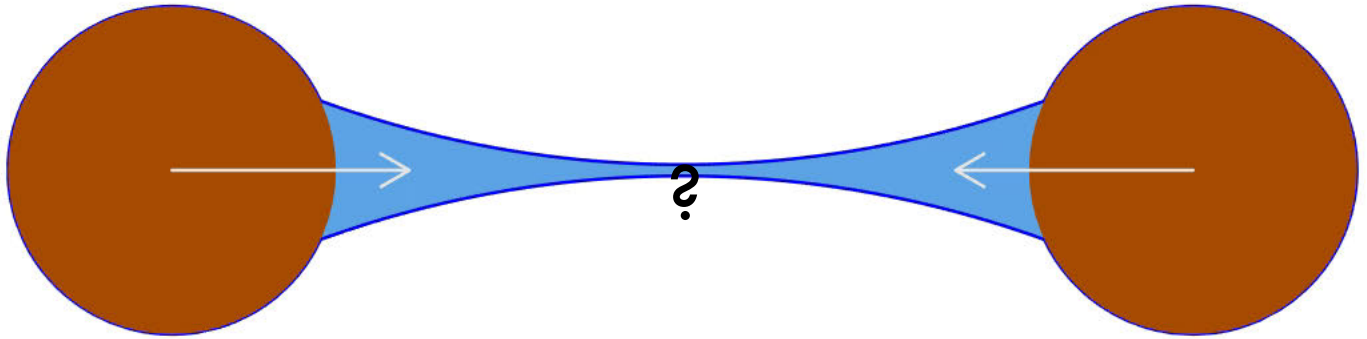


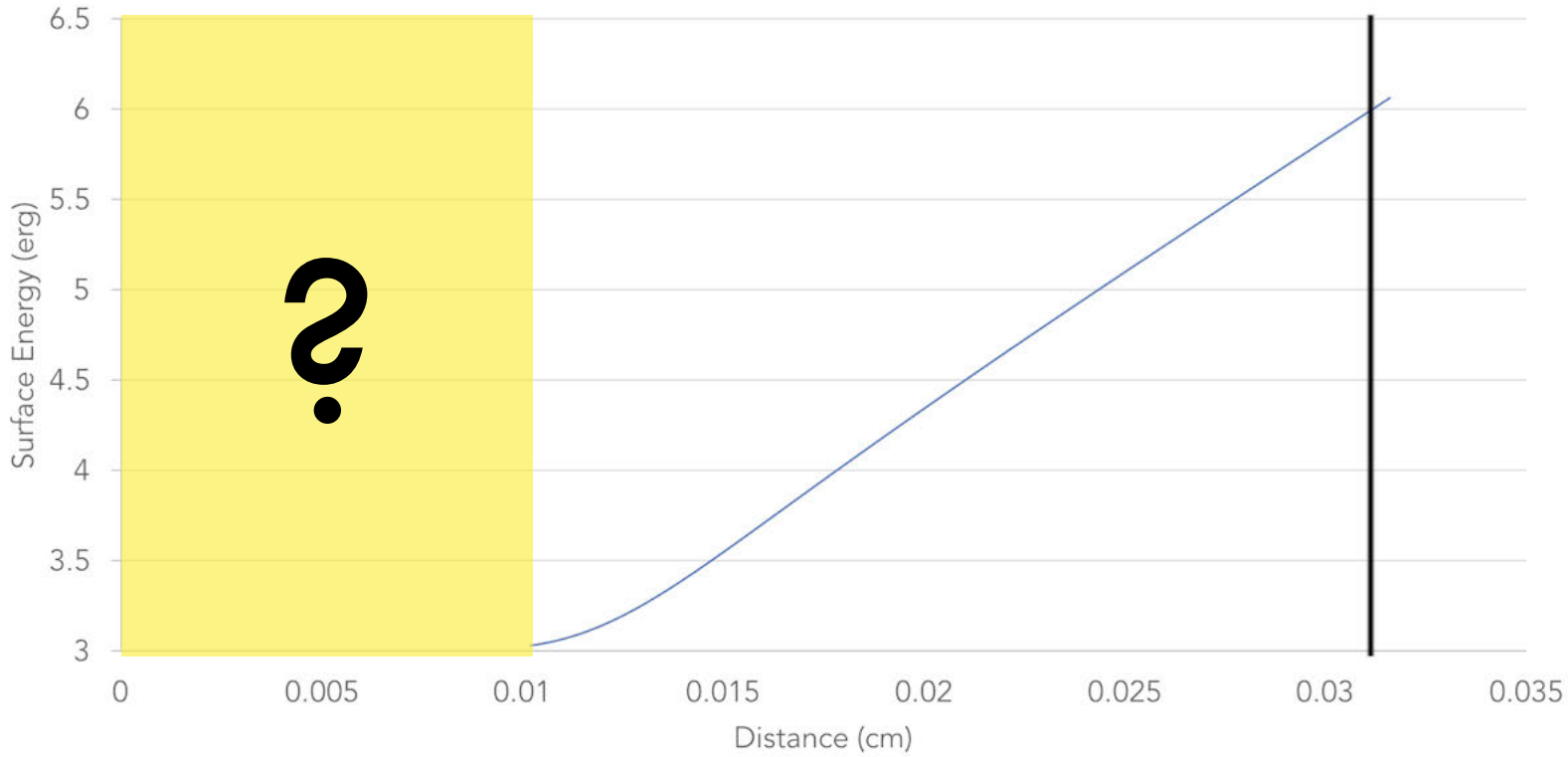
$$f\mathrm{d}s = -\frac{\partial \mathrm{d}E_s}{\partial d} = -\left(\frac{\partial \mathrm{d}E_s}{\partial R}\cdot\frac{\partial R}{\partial d} + \sum_{i=1,2}\frac{\partial \mathrm{d}E_s}{\partial \alpha_i}\cdot\frac{\partial \alpha_i}{\partial d}\right)$$

Analytical Model

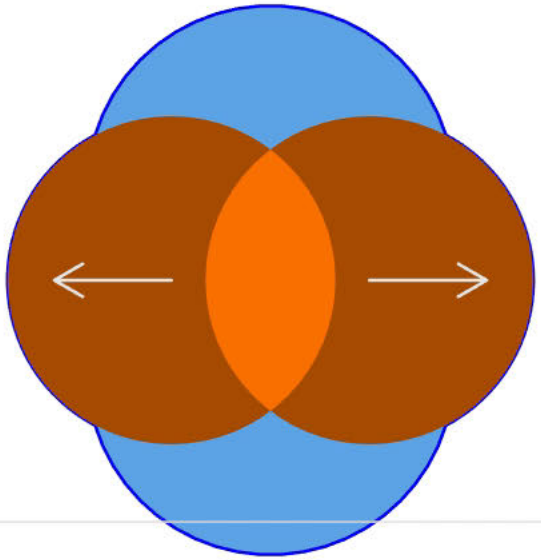


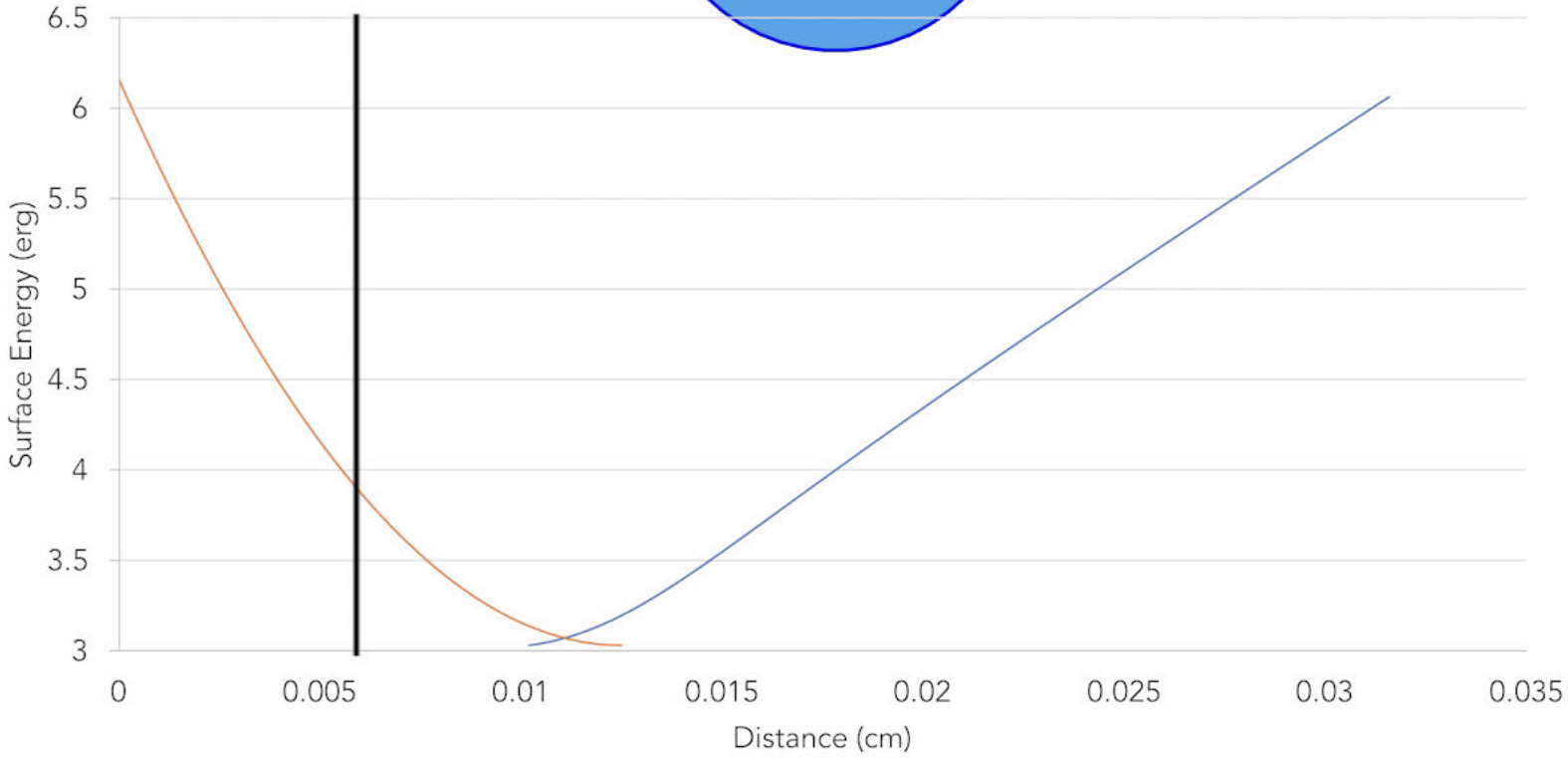



?

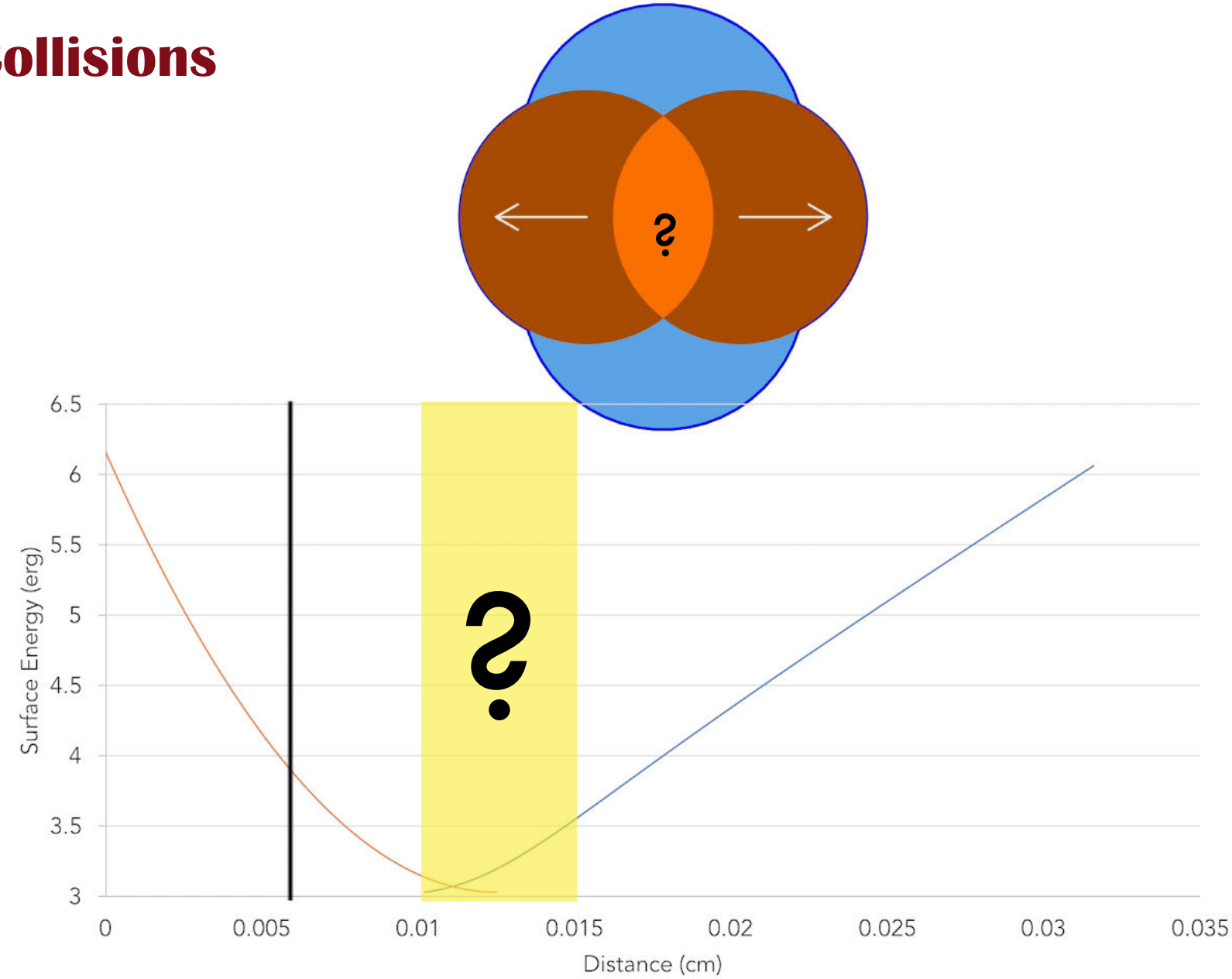

?
Surface Energy (erg)
6.5
6
5.5
5
4.5
4
3.5
3
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
Distance (cm)

Handle Collisions

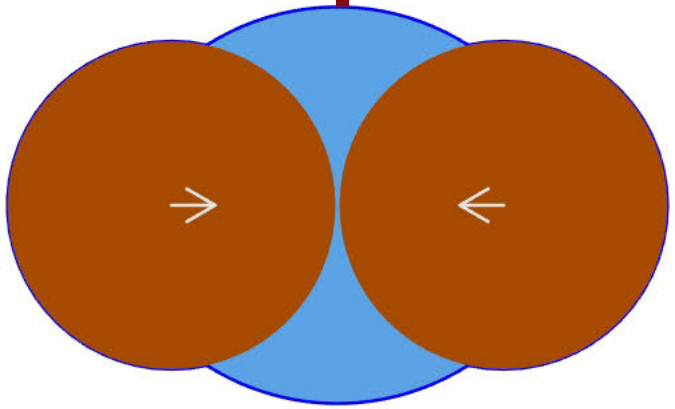


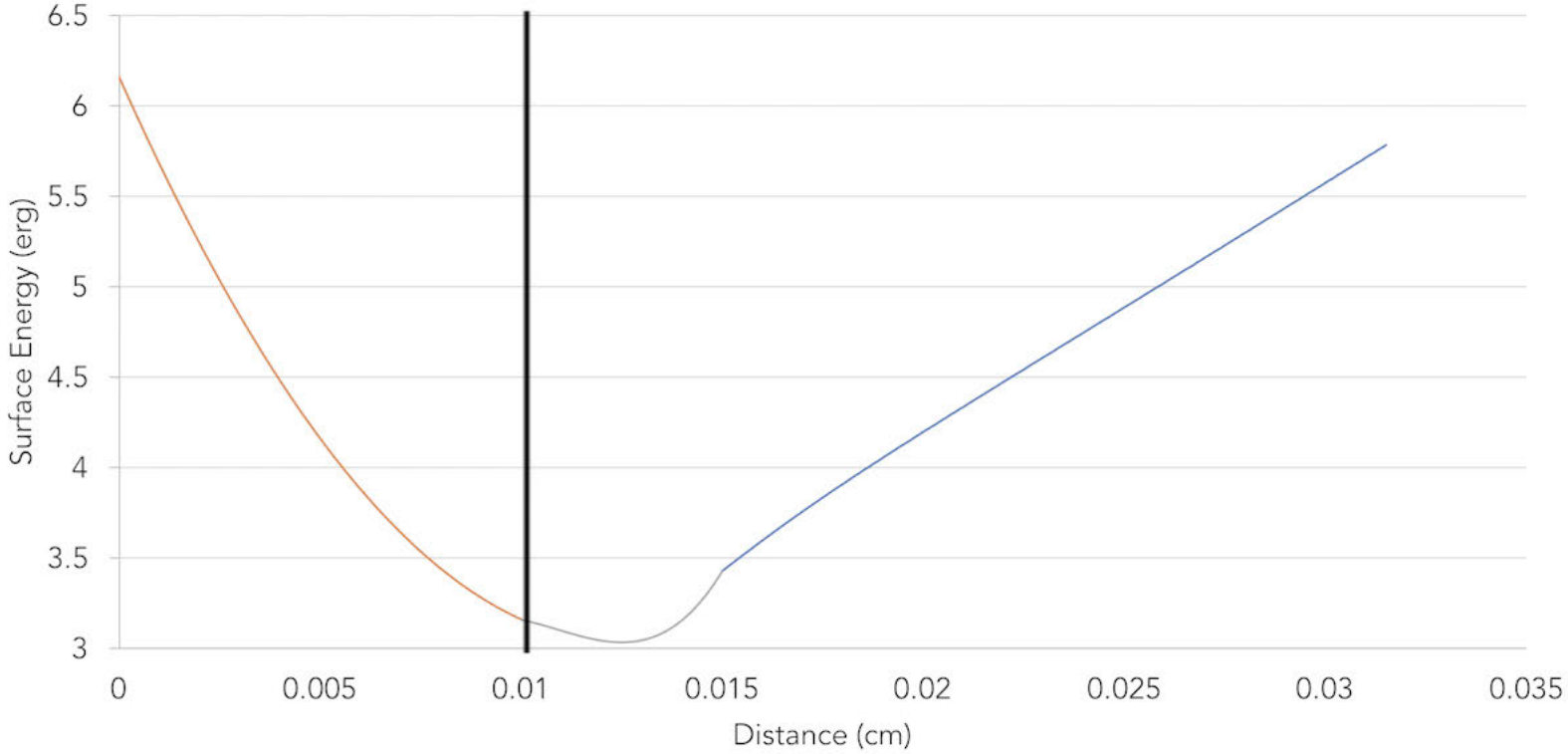


Handle Collisions

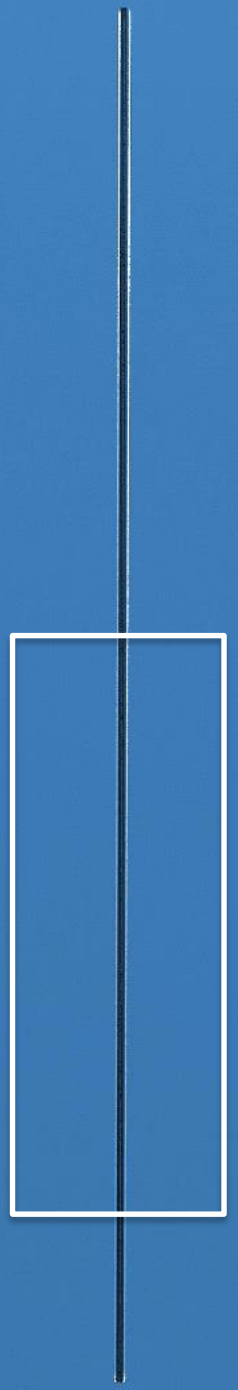


Interpolate between Cohesive & Repulsive Effect

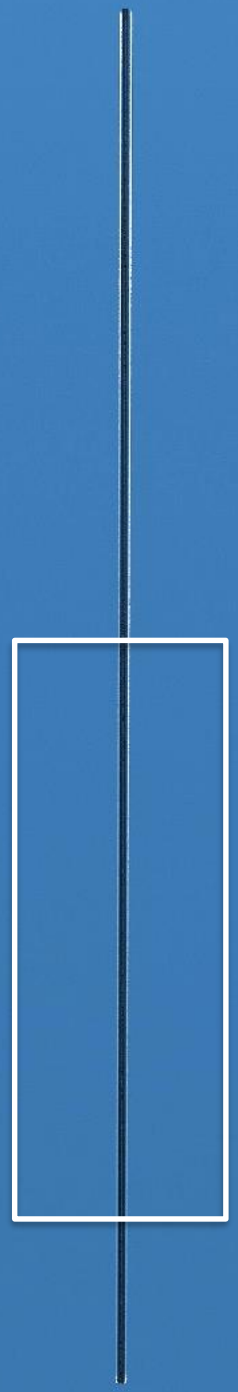




Discretized Cohesive Force

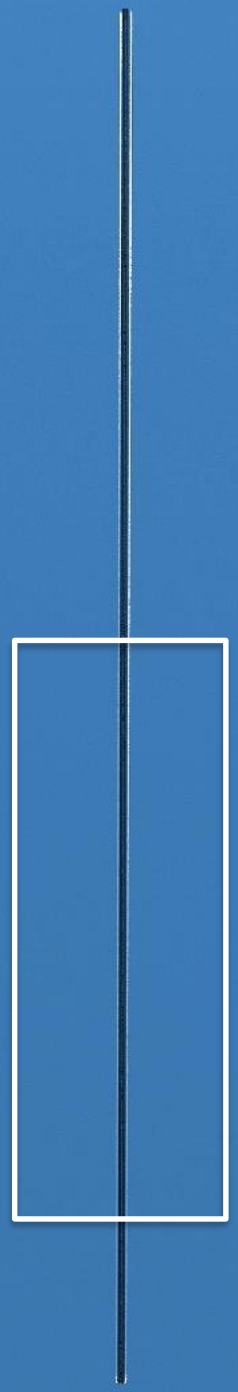


Discontinuous Motion

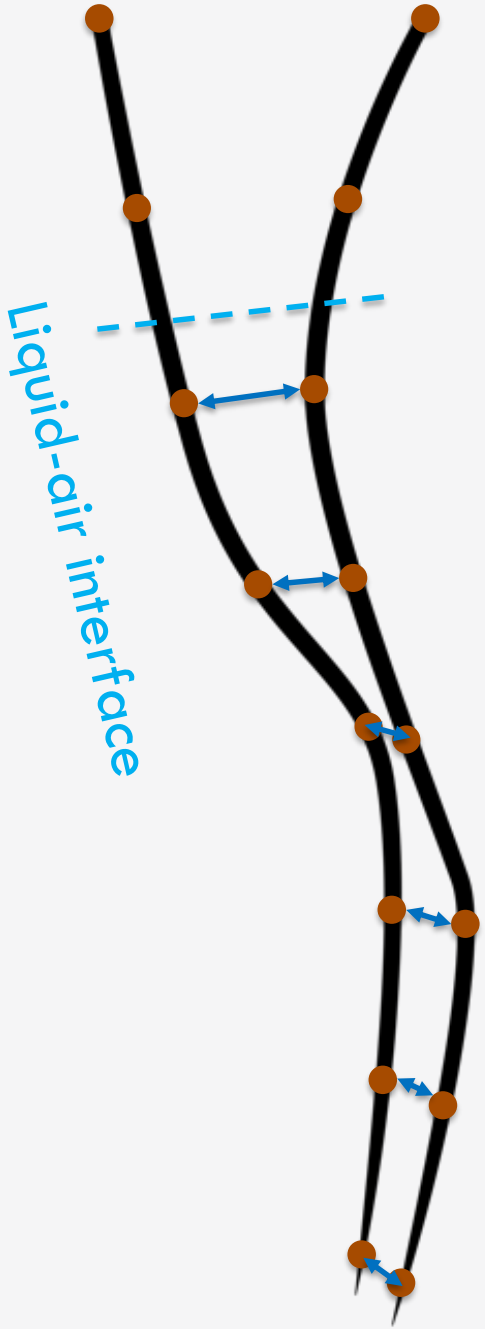


Discontinuous Motion

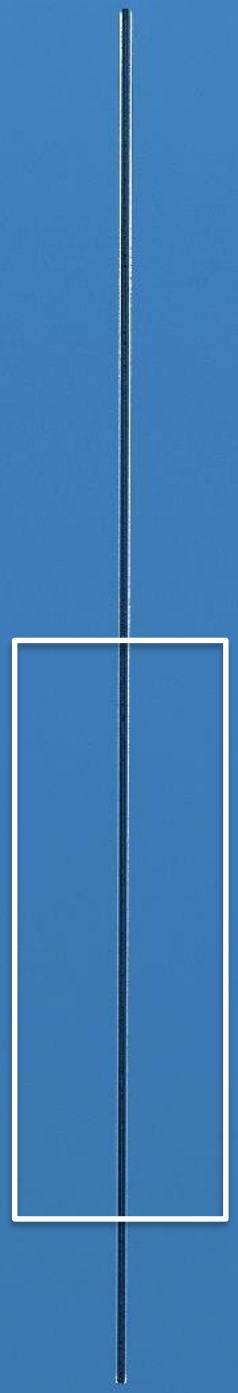
Naïve Solution



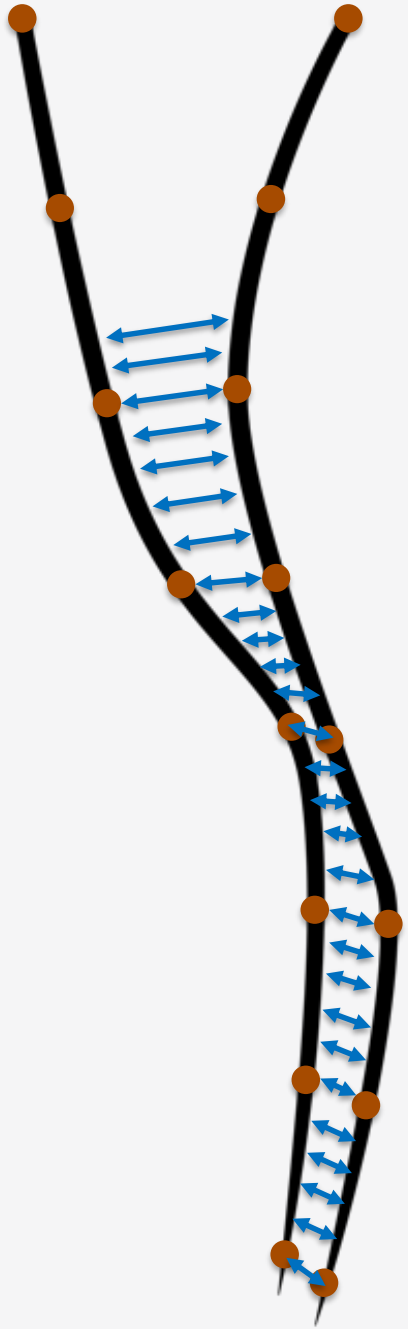
Discontinuous Motion



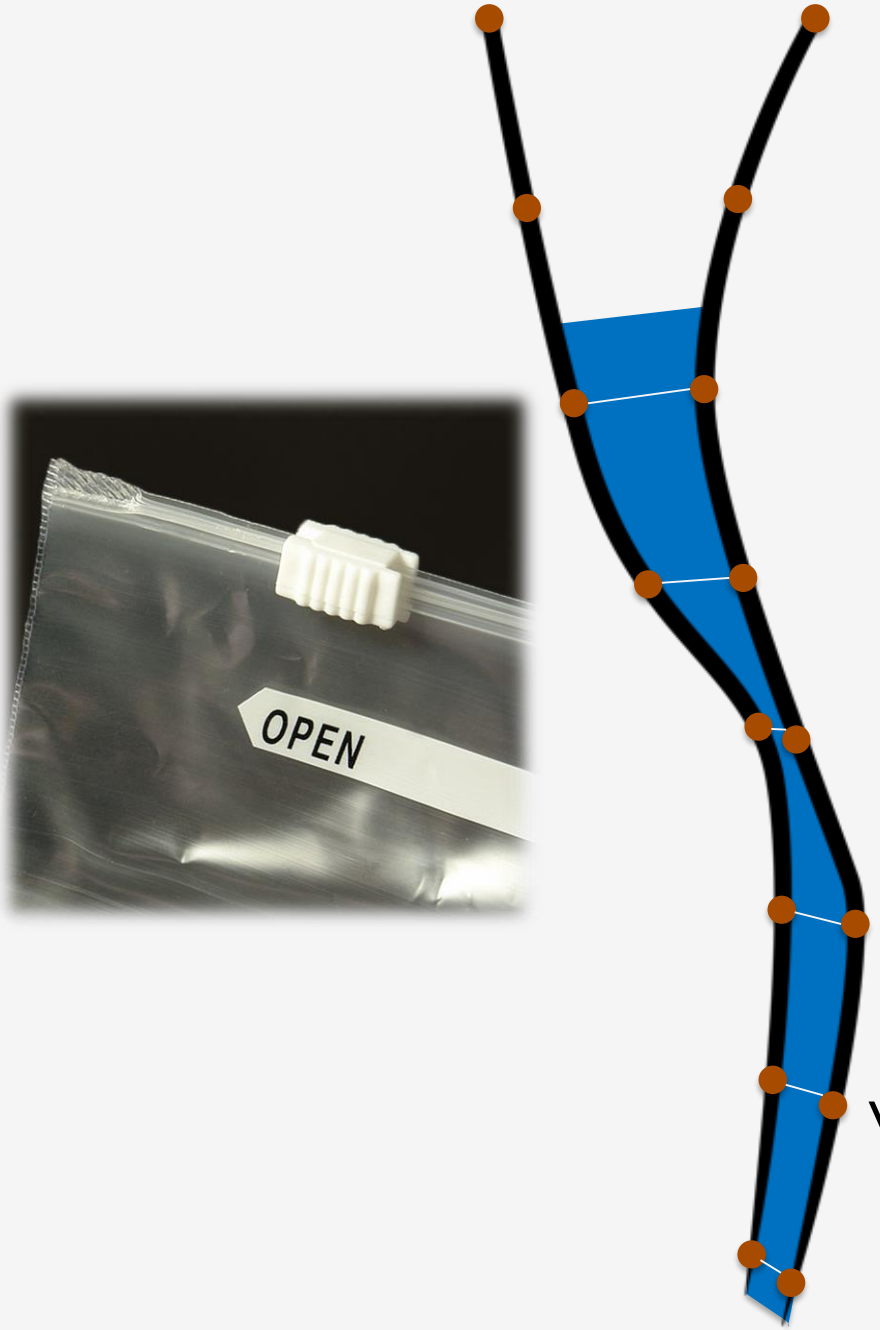
Naïve Solution



Discontinuous Motion



Over-Sampling



Variable Quadrature

Cohesion OFF

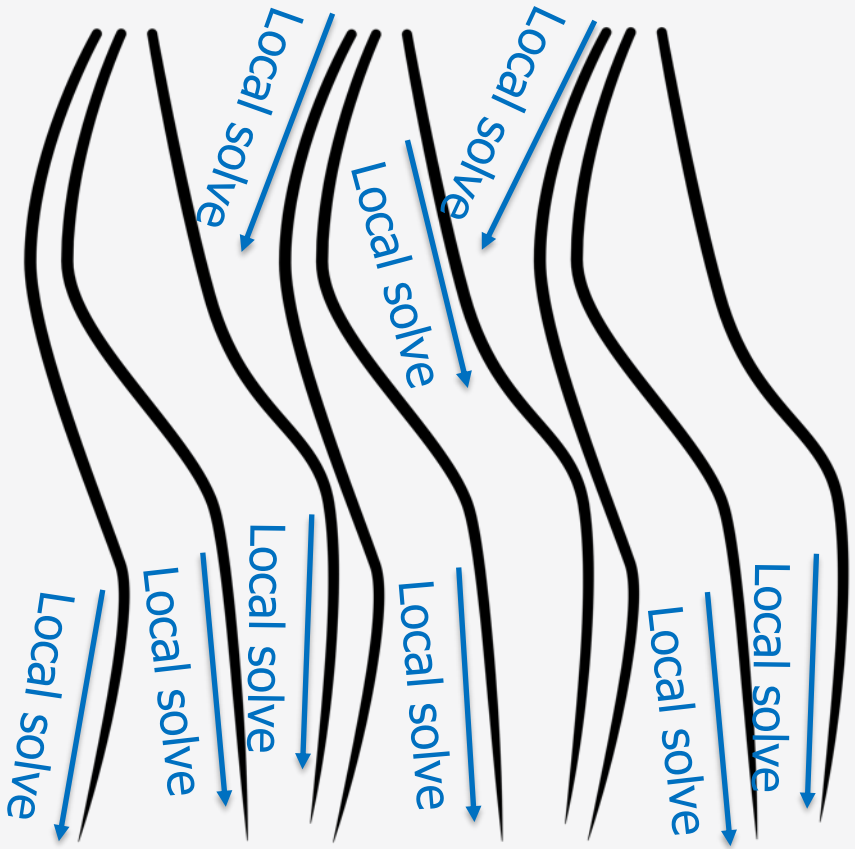
Constant Quadrature

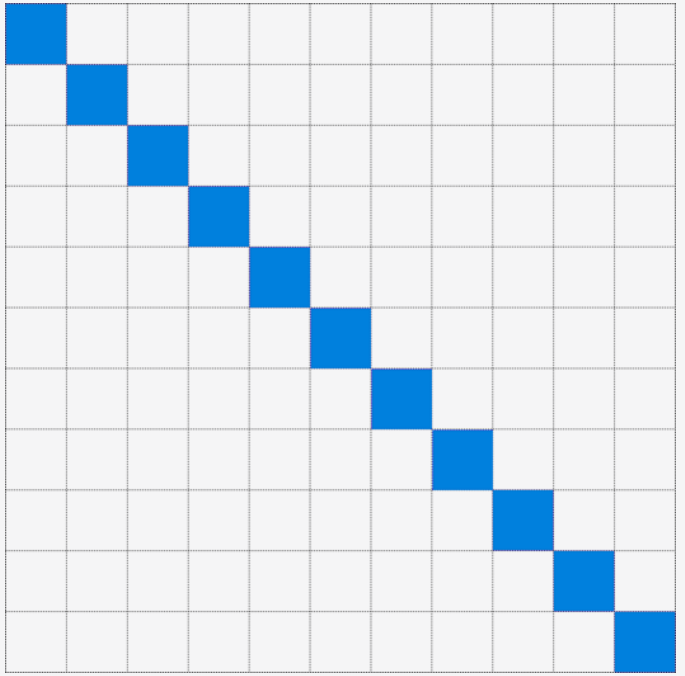
Variable Quadrature

Our Simulation

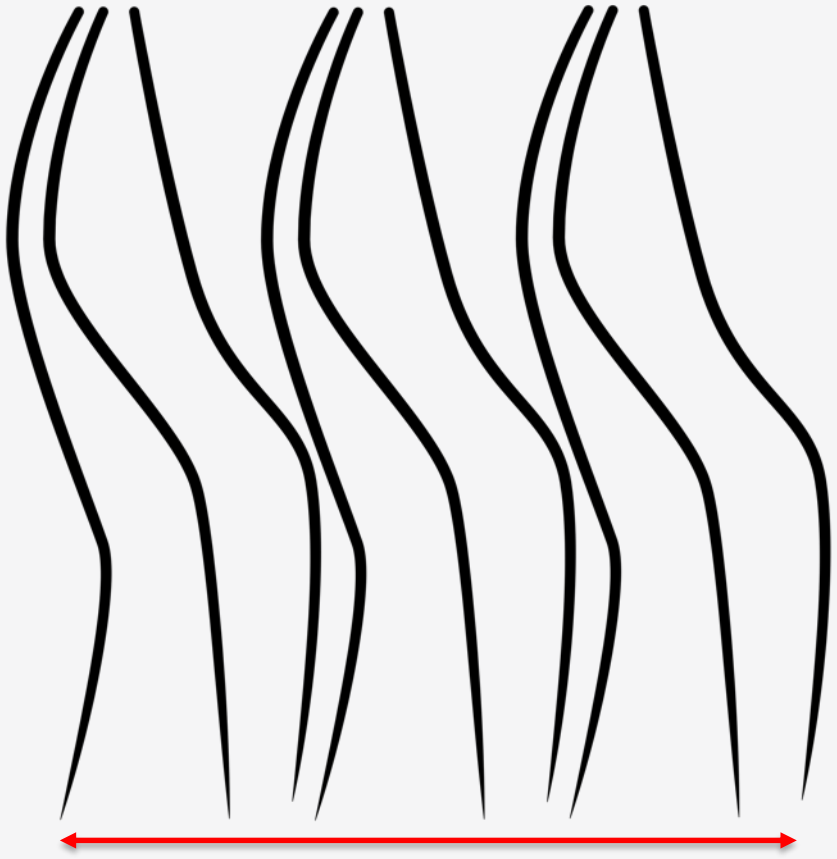
Real Experiment [Bico et al. 2004]

Preconditioning with Local Solves

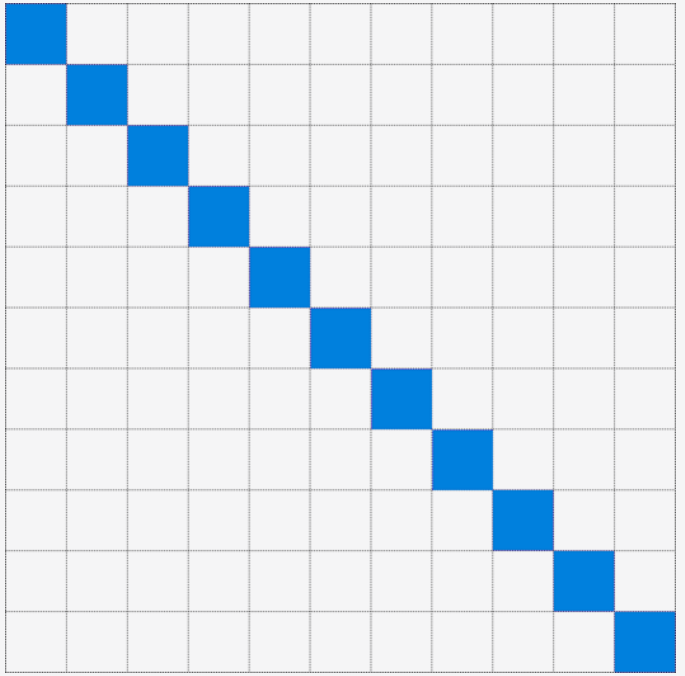




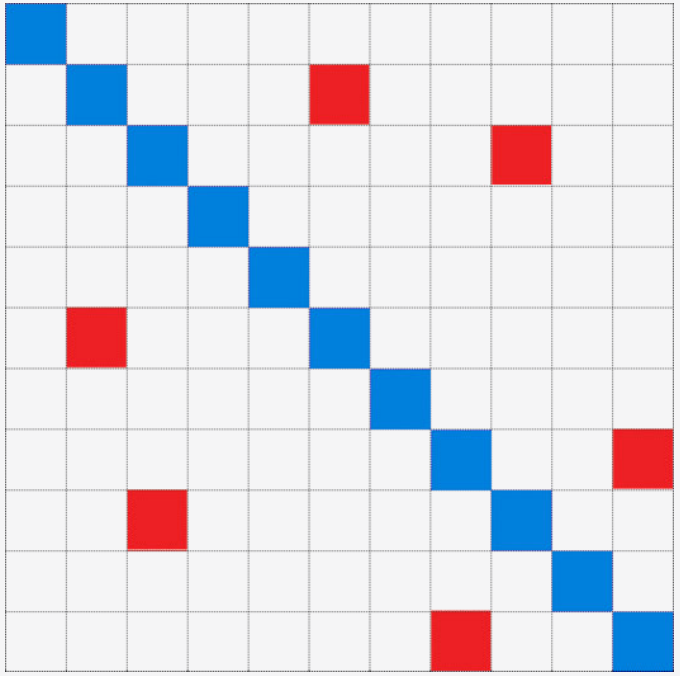
Pre-factorized LDLT in Parallel



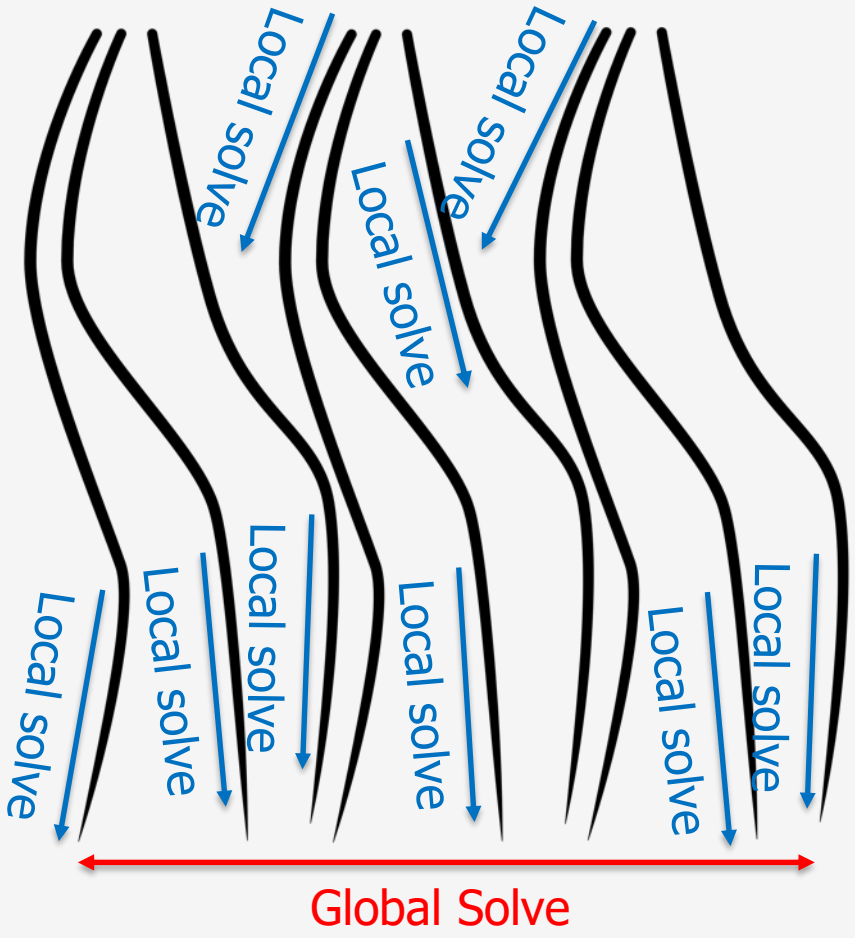
Global Solve

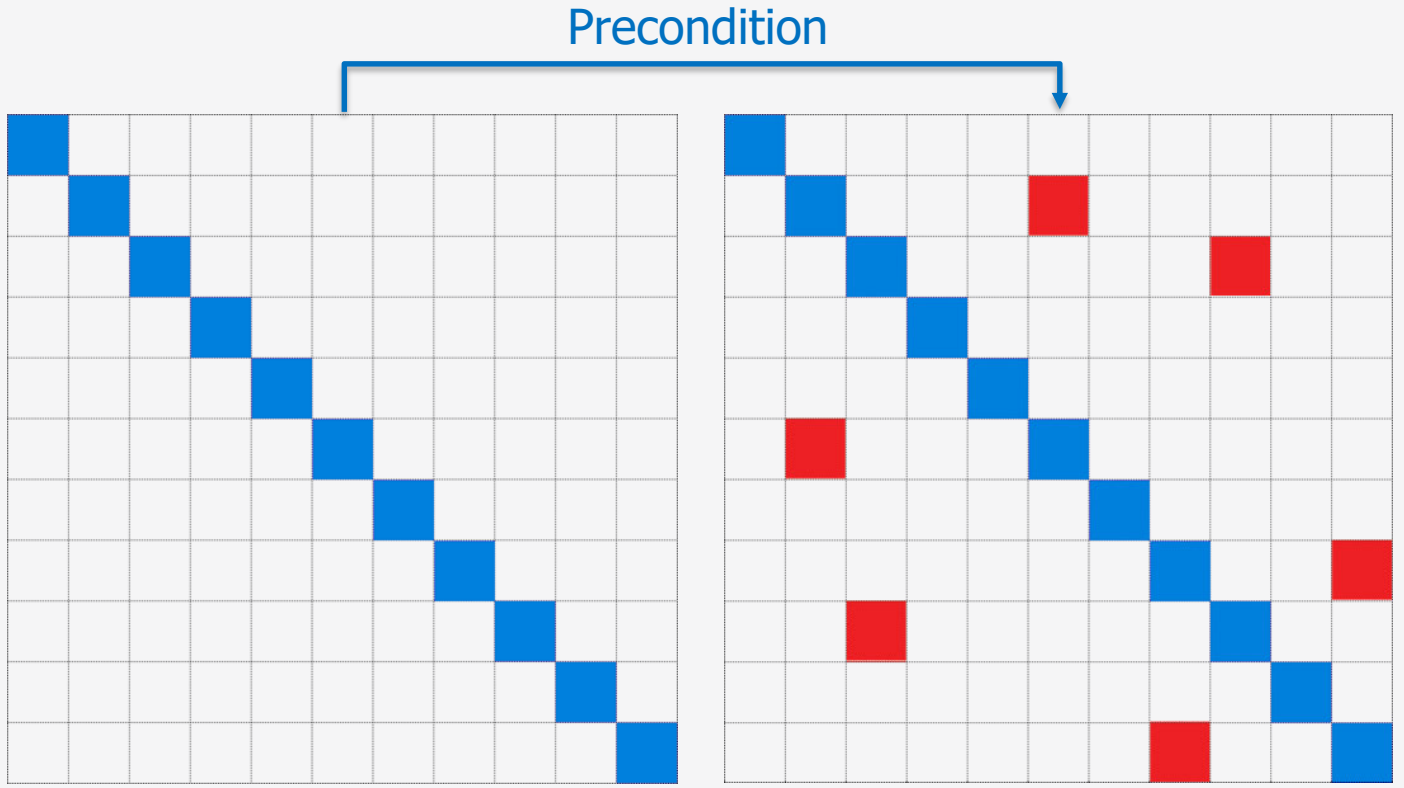


Pre-factorized LDLT in Parallel



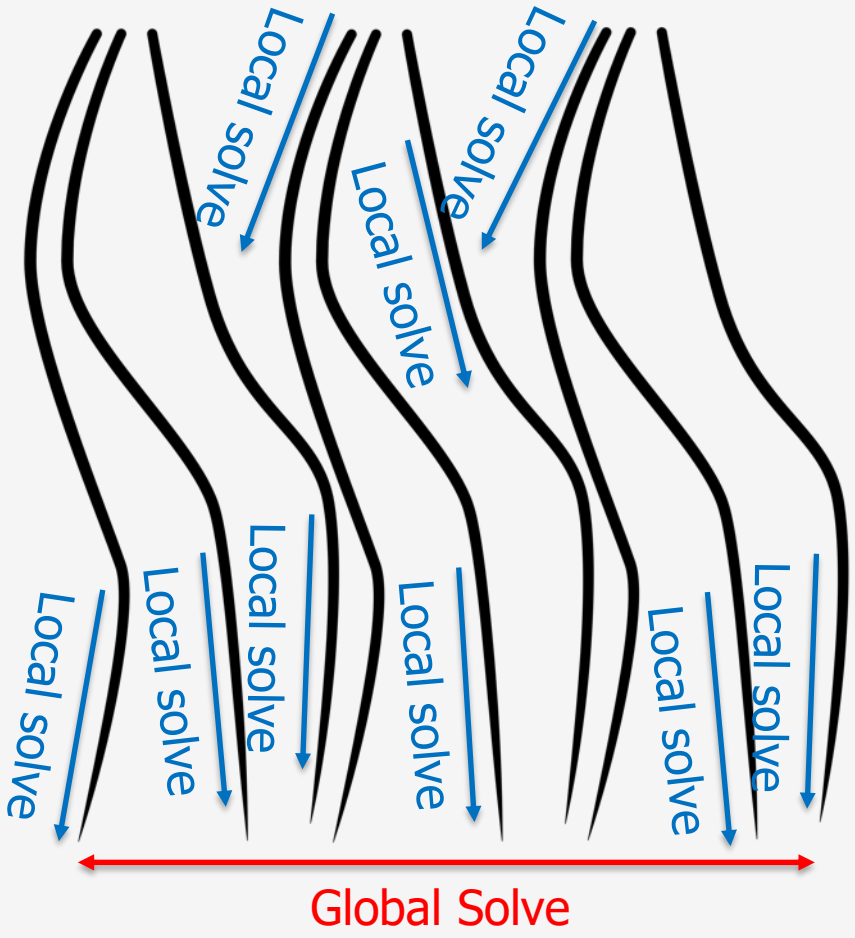
Preconditioned Conjugate Gradient

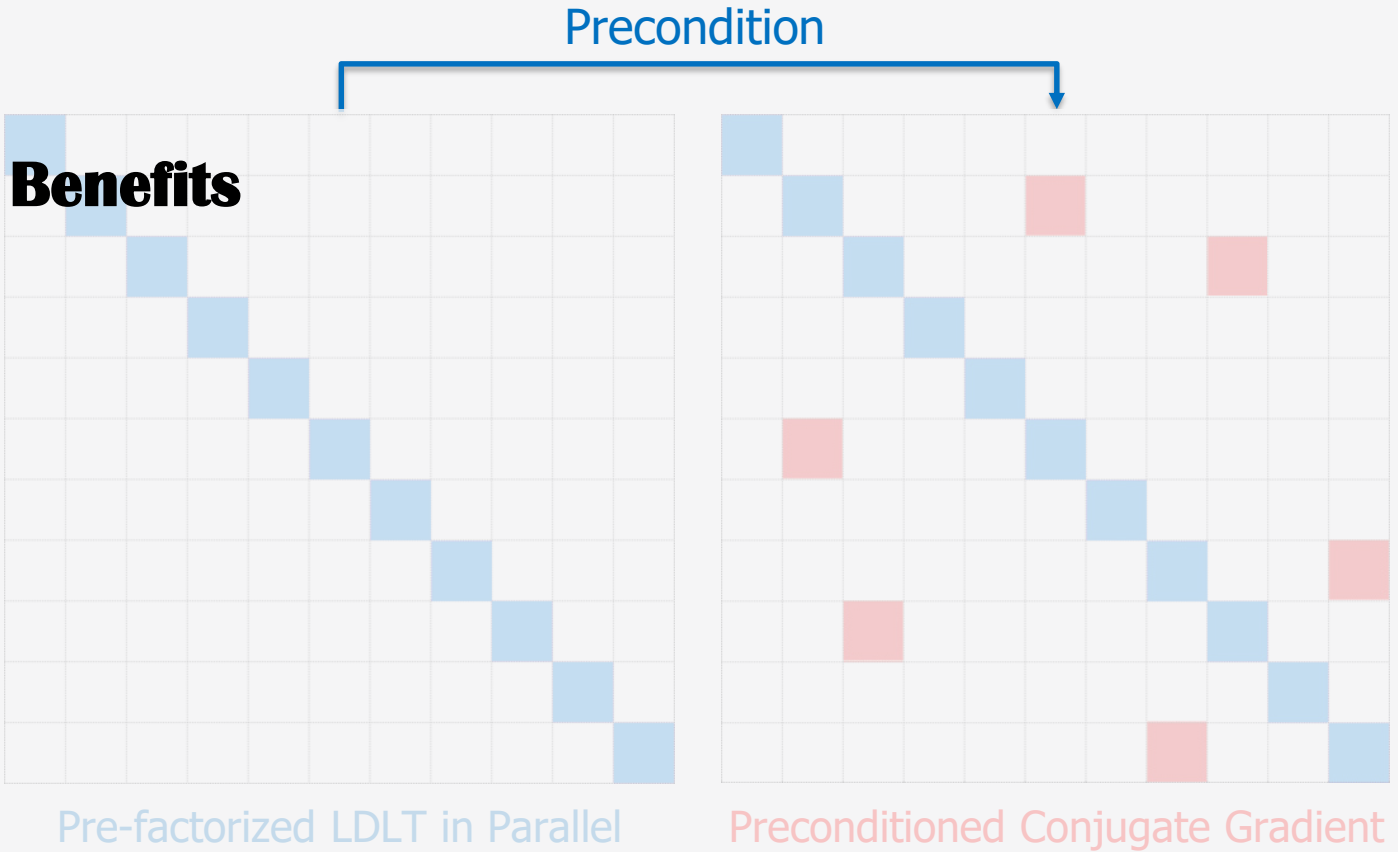


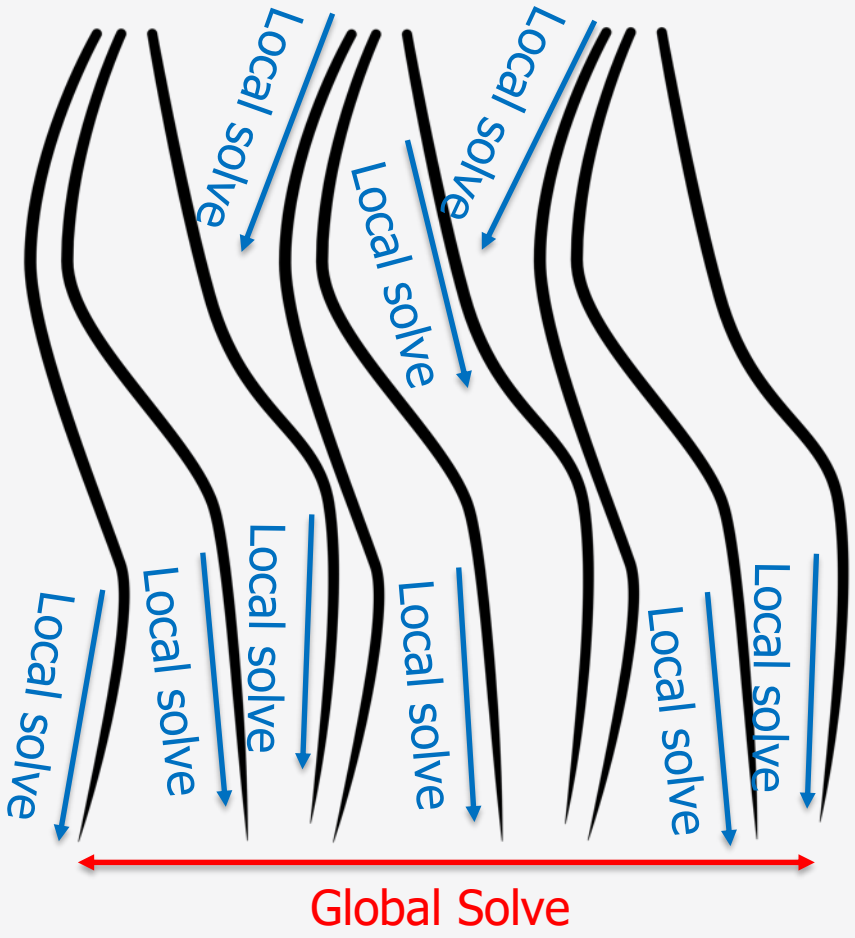


Pre-factorized LDLT in Parallel

Preconditioned Conjugate Gradient


Local Solve
Local Solve
Local solve
Local solve
Local solve
Local solve
Local solve
Local solve
Local solve
Global Solve


Precondition
Benefits
Pre-factorized LDLT in Parallel
Preconditioned Conjugate Gradient



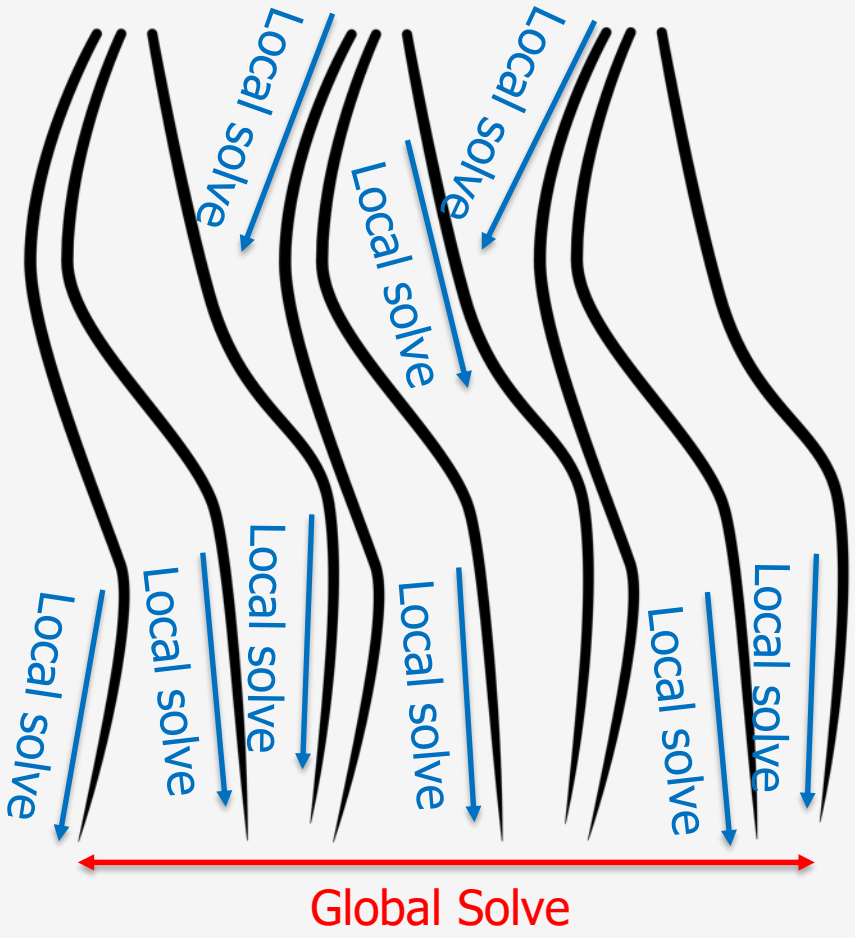
Precondition

Benefits

Exact local solves to minimize stretching.

Pre-factorized LDLT in Parallel

Preconditioned Conjugate Gradient



Precondition

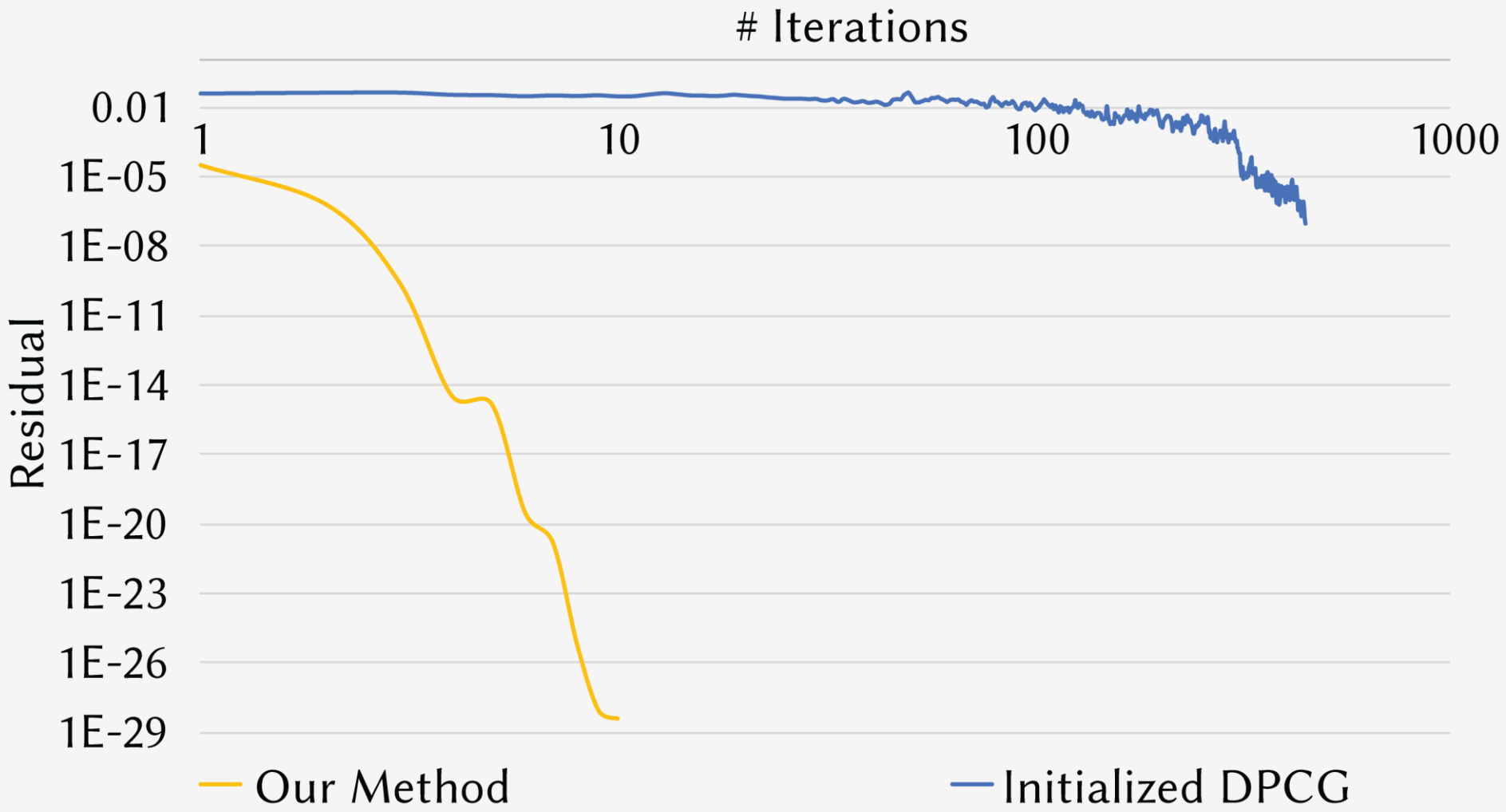
Benefits

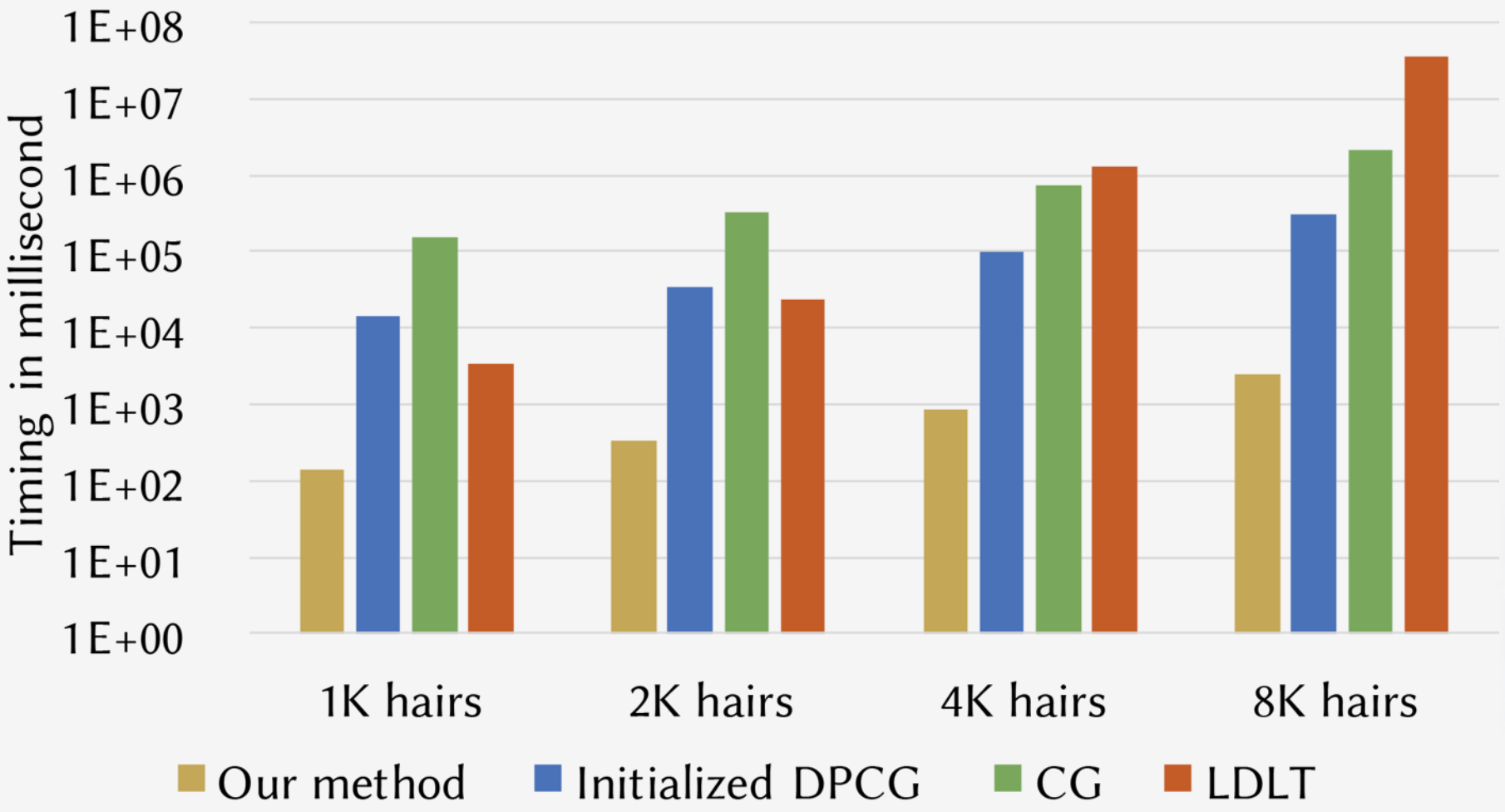
Exact local solves to minimize stretching.

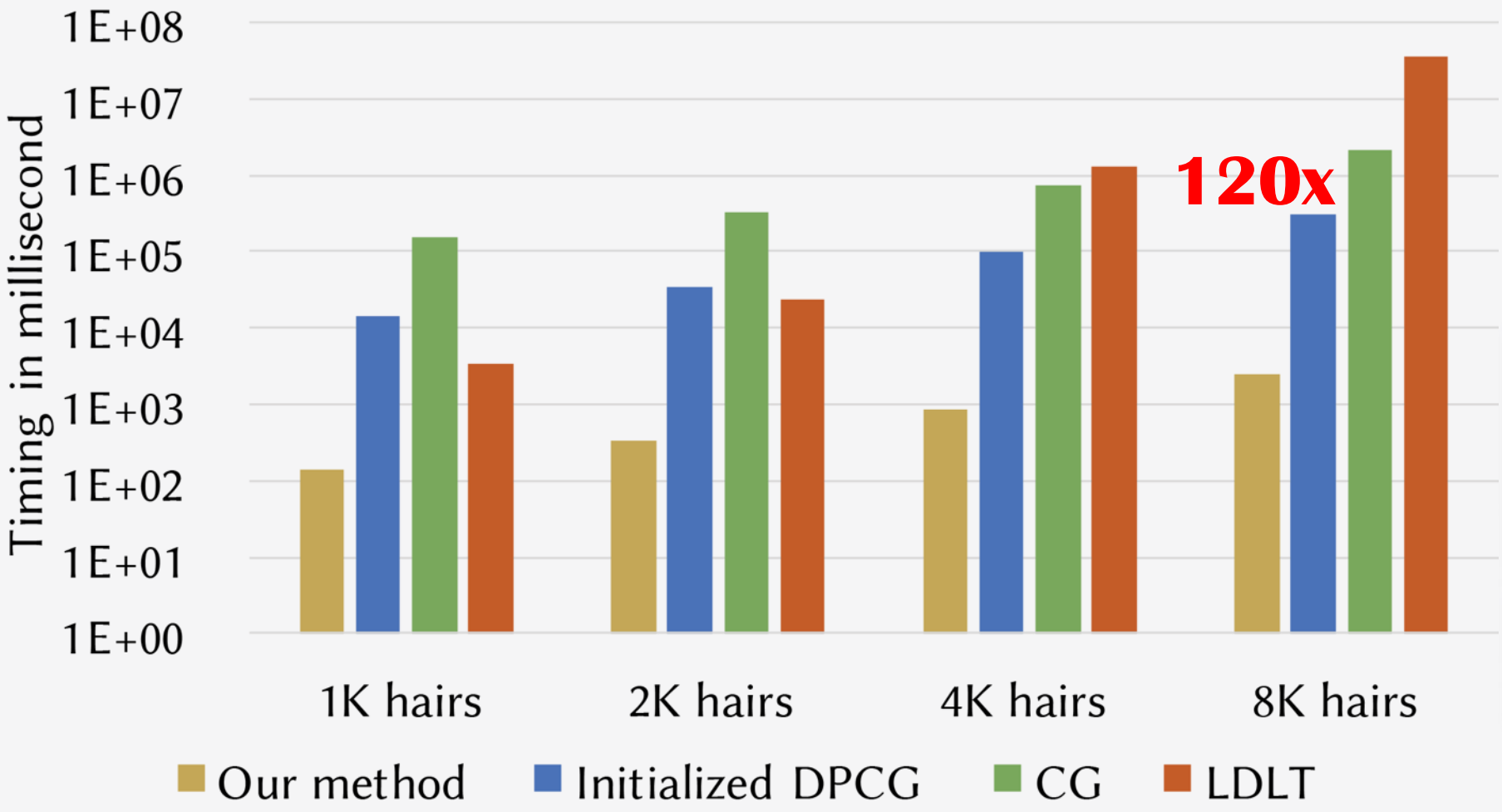
Similarity between the local and global matrices increases the rate of convergence.

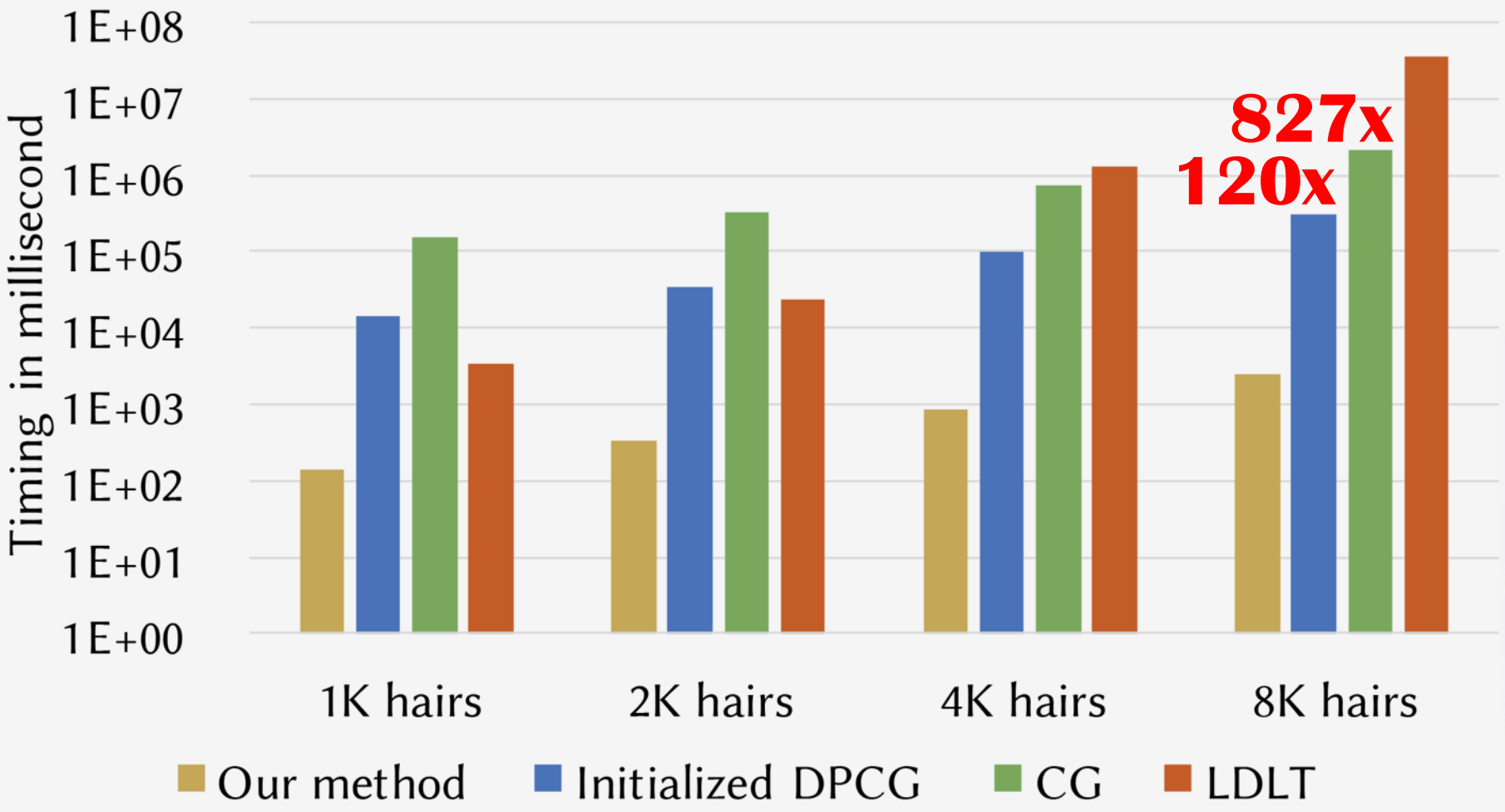
Pre-factorized LDLT in Parallel

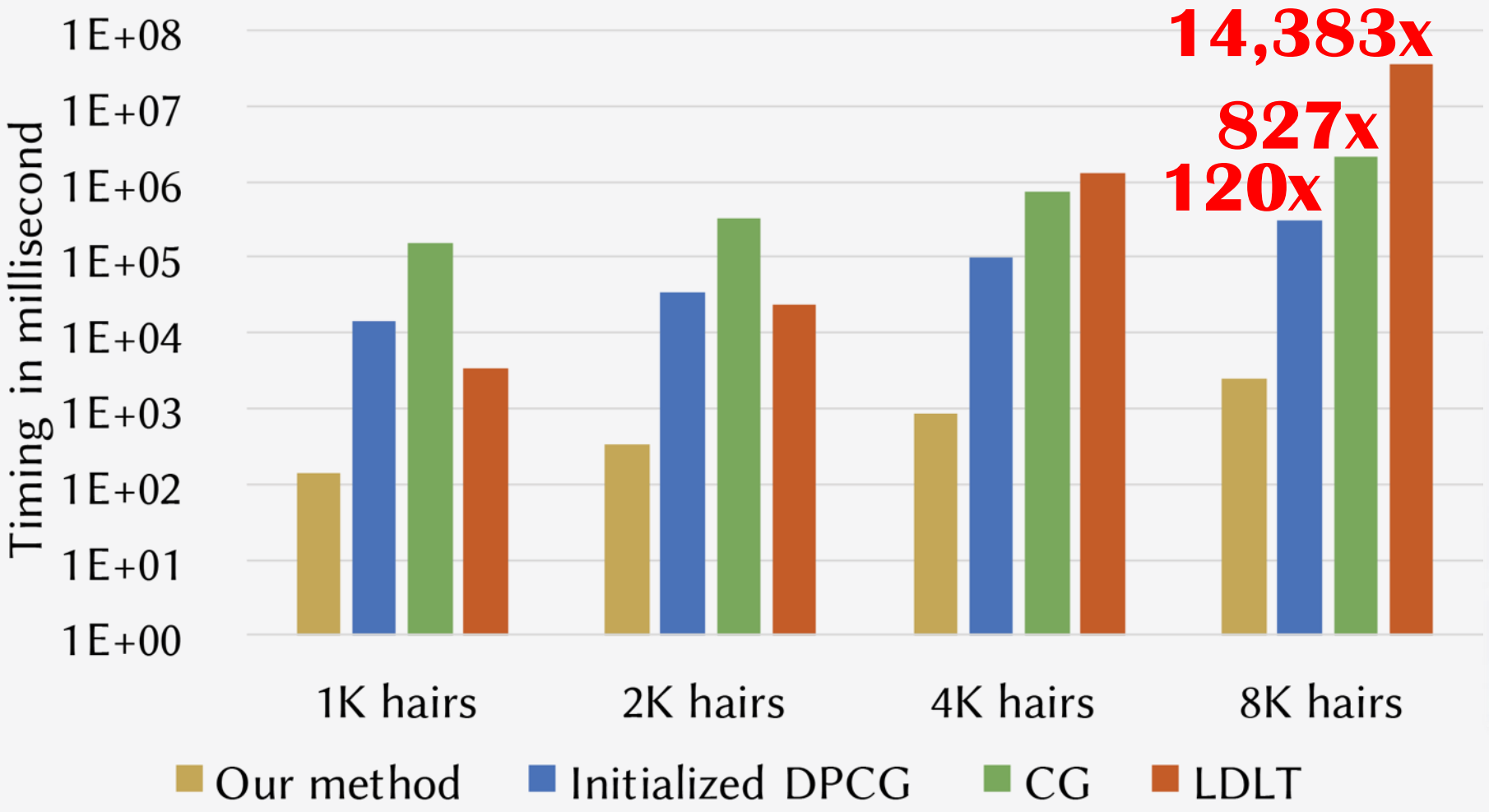
Preconditioned Conjugate Gradient


Iterations
0.01
1E-05
1E-08
1E-11
1E-14
1E-17
1E-20
1E-23
1E-26
1E-29
Residual
1
10
100
1000
Our Method
Initialized DPCG

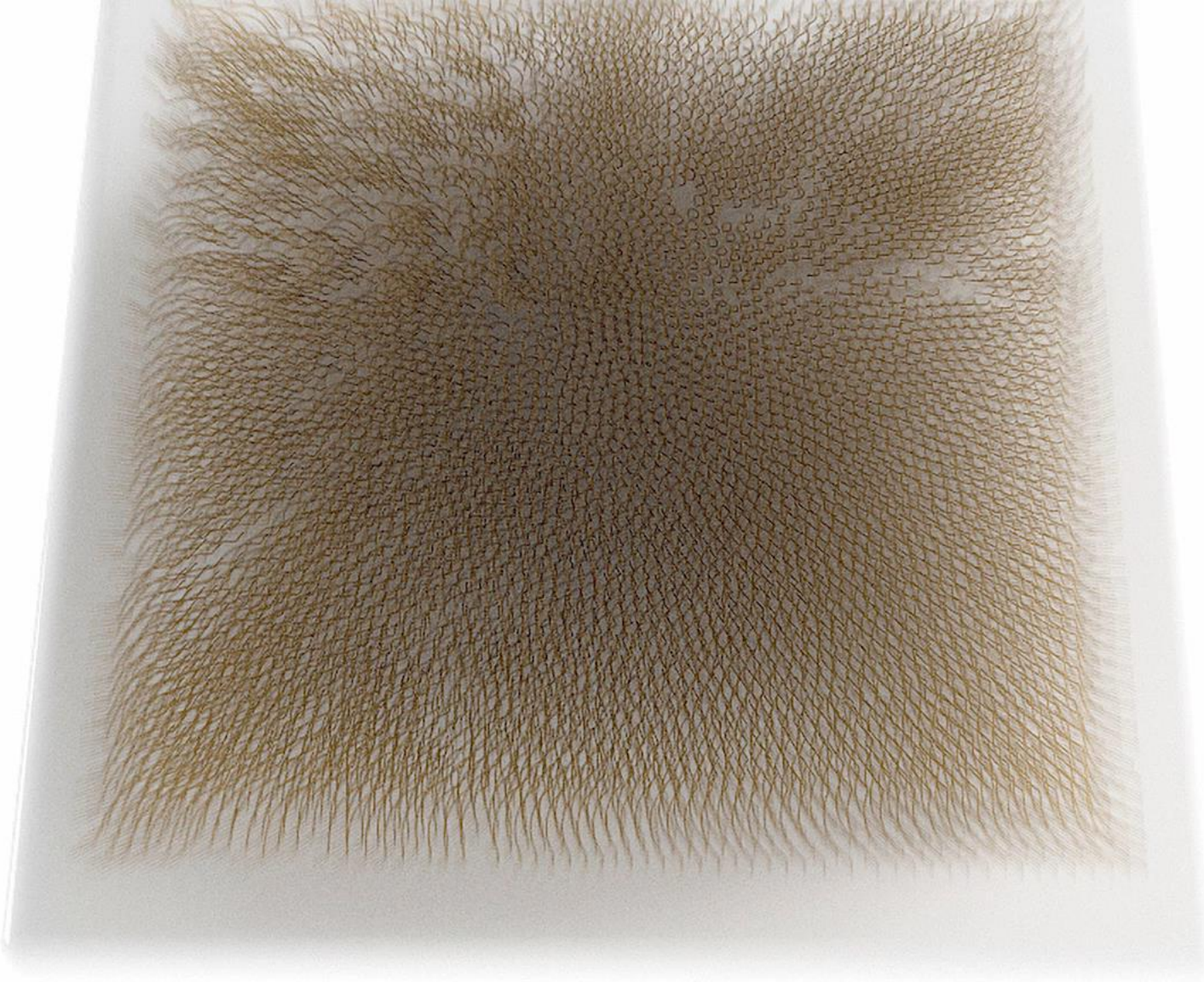

Timing in millisecond
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
1K hairs
2K hairs
4K hairs
8K hairs
Our method
Initialized DPCG
CG
LDLT


Timing in millisecond
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
120x
1K hairs
2K hairs
4K hairs
8K hairs
Our method
Initialized DPCG
CG
LDLT


Timing in millisecond
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
827x
120x
1K hairs
2K hairs
4K hairs
8K hairs
Our method
Initialized DPCG
CG
LDLT

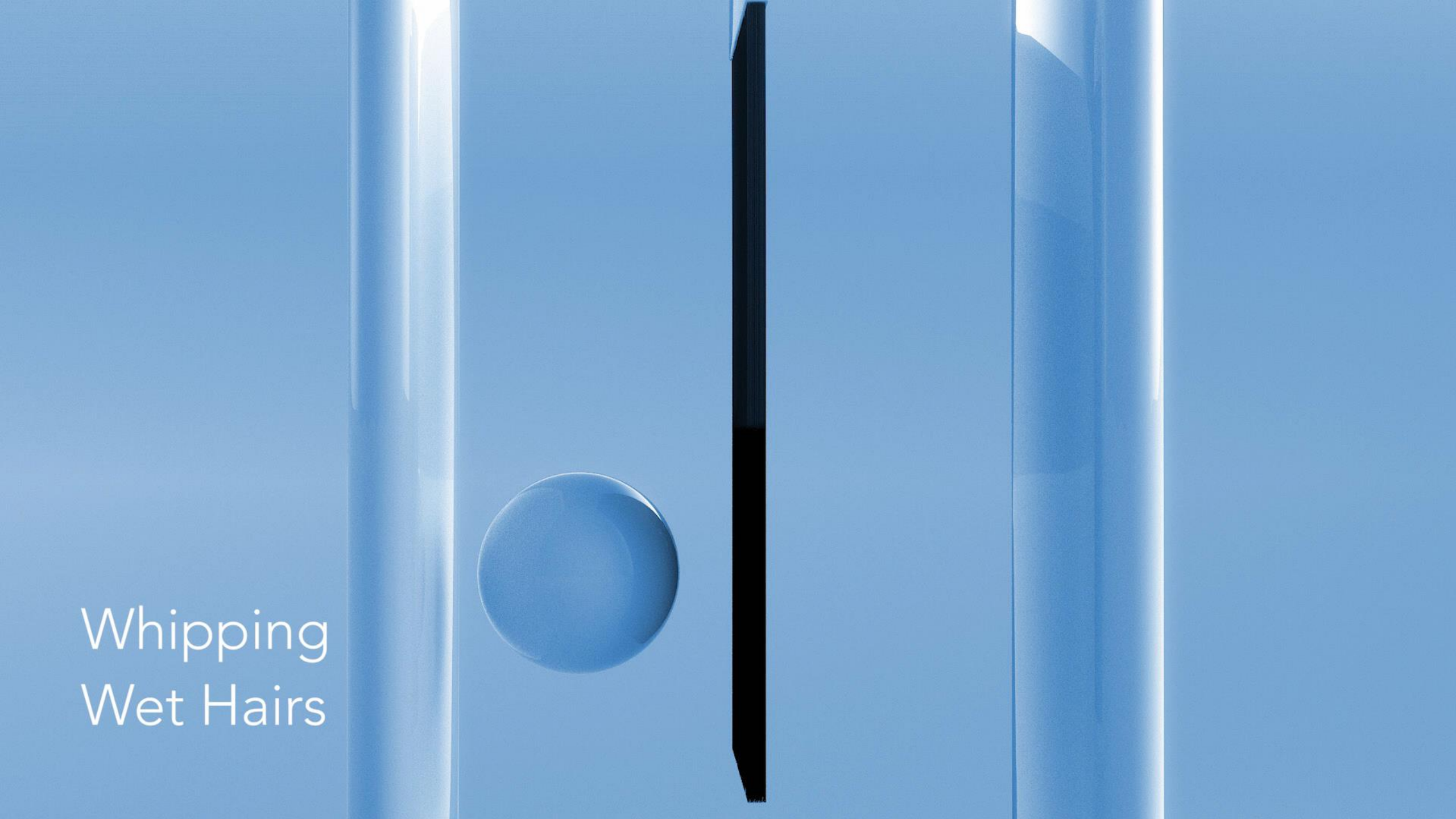

14,383x
827x
120x
1E+08
1E+07
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
Timing in millisecond
1K hairs
2K hairs
4K hairs
8K hairs
Our method
Initialized DPCG
CG
LDLT

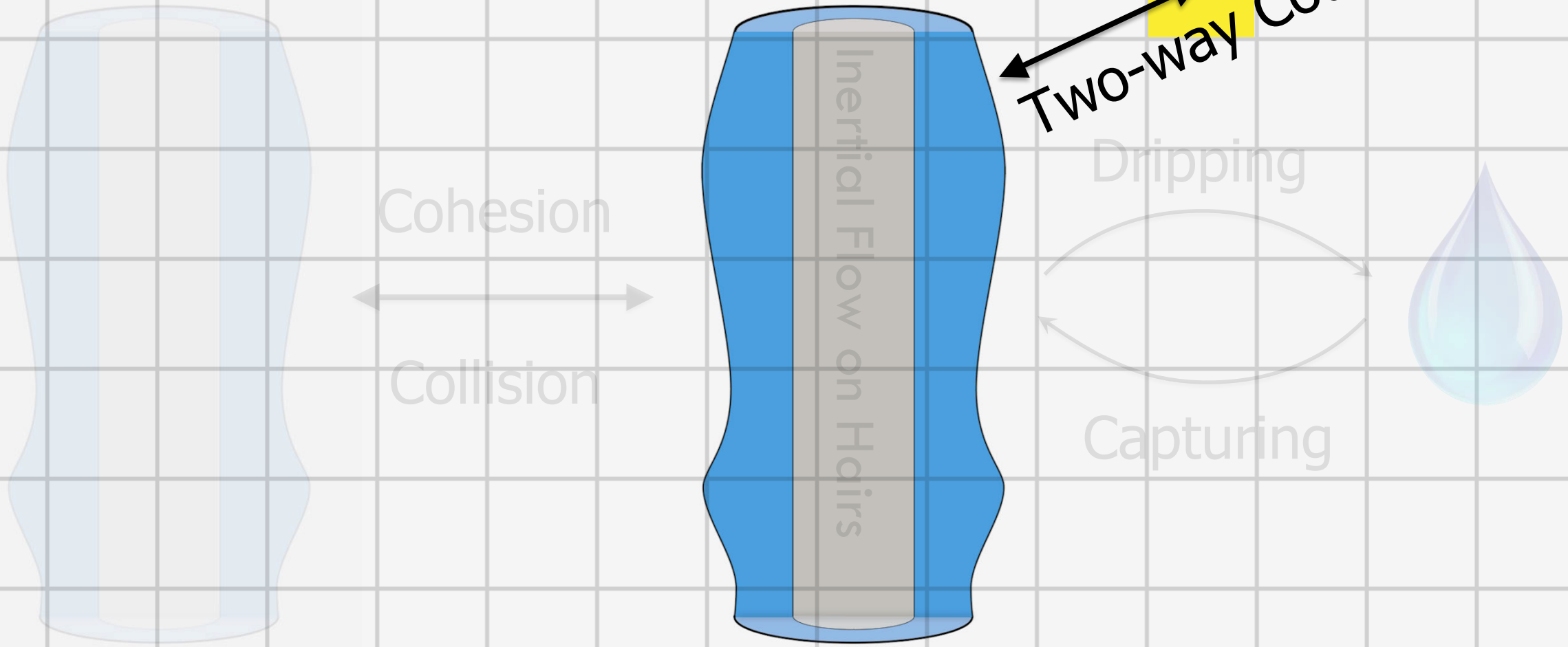
Complicated Cohesion Effects



Water on
Mat of Fur

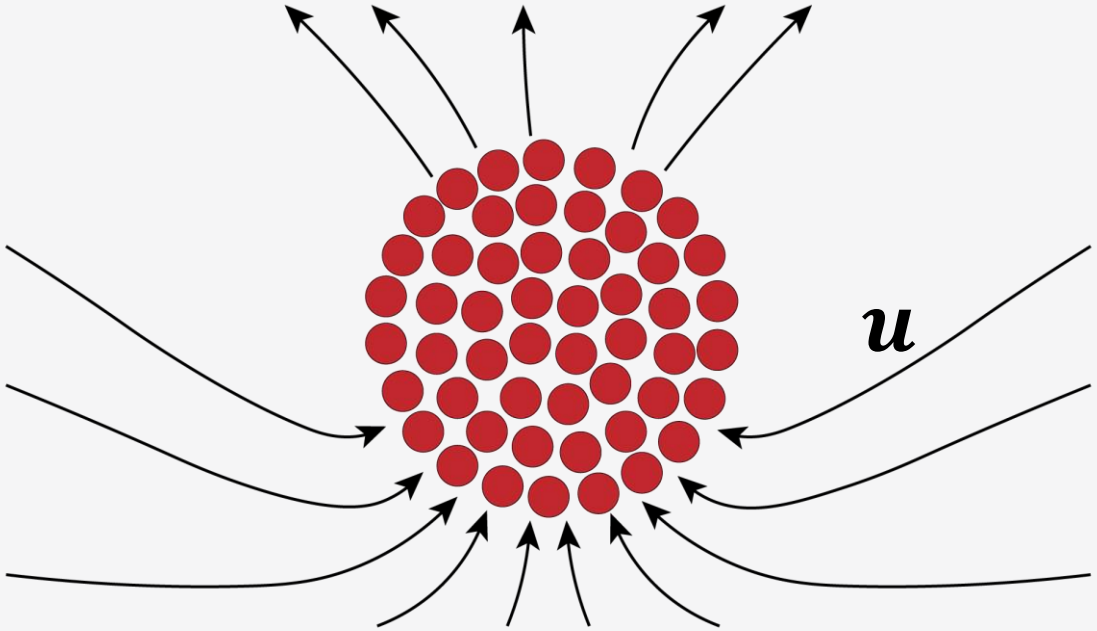
1/2x replay


Whipping
Wet Hairs

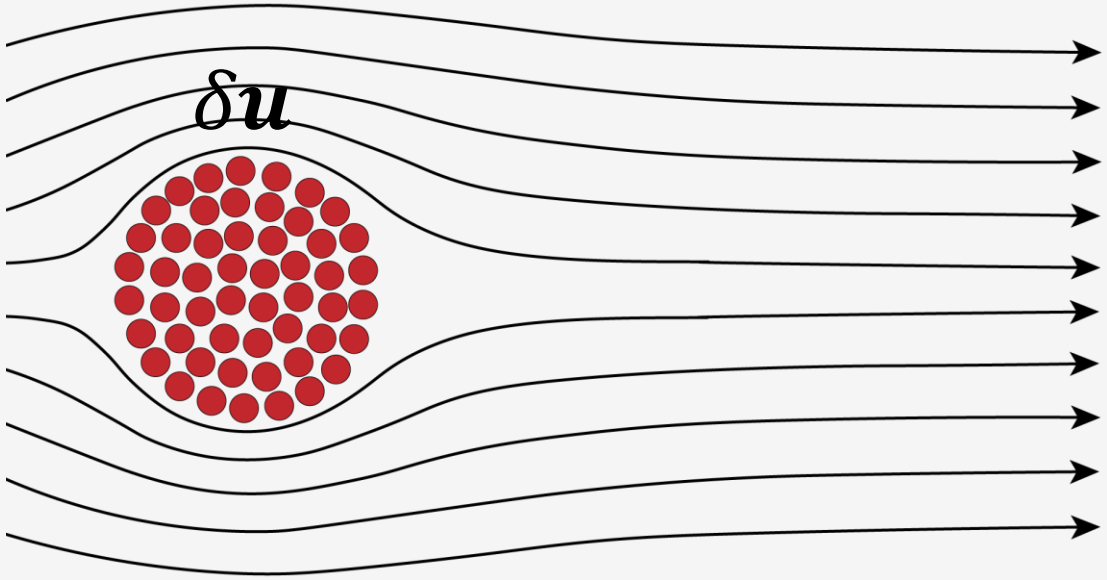

Two-way Coupling
Inertial Flow on Hairs
Cohesion
Collision
Dripping
Capturing

Hairs and Liquid as a Continuum

Related to [Daviet & Bertails-Descoubes 2017, Tampubolon et al. 2017]



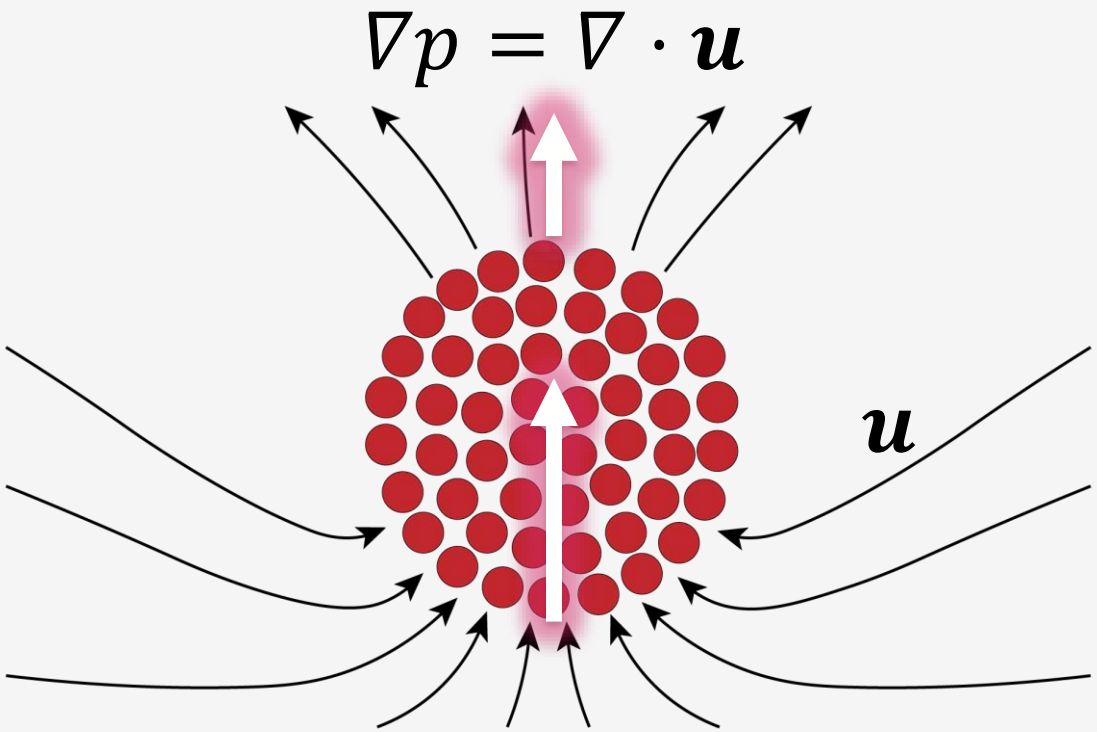
Reversible Pressure Gradient
(Buoyancy)



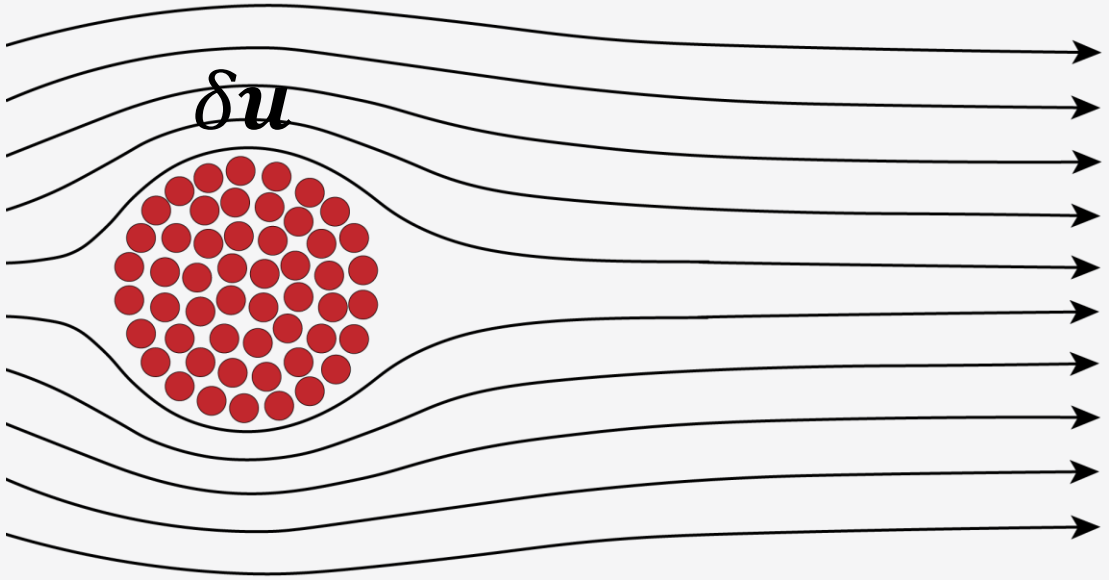
Viscous Drag Force
(Friction)

Hairs and Liquid as a Continuum

Related to [Daviet & Bertails-Descoubes 2017, Tampubolon et al. 2017]



Reversible Pressure Gradient
(Buoyancy)

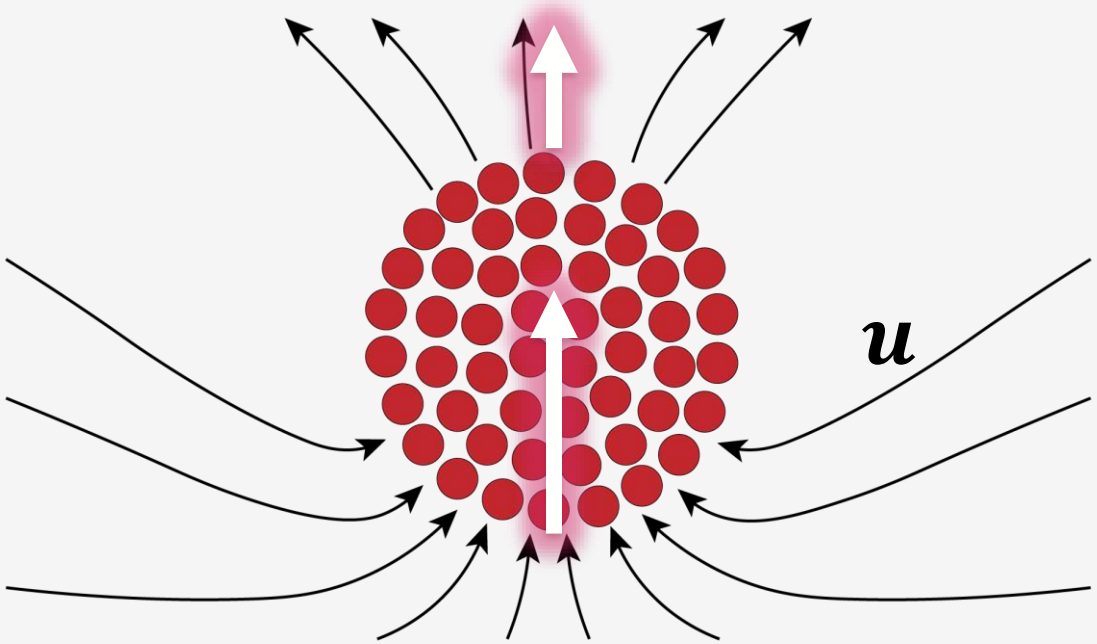


Viscous Drag Force
(Friction)

Hairs and Liquid as a Continuum

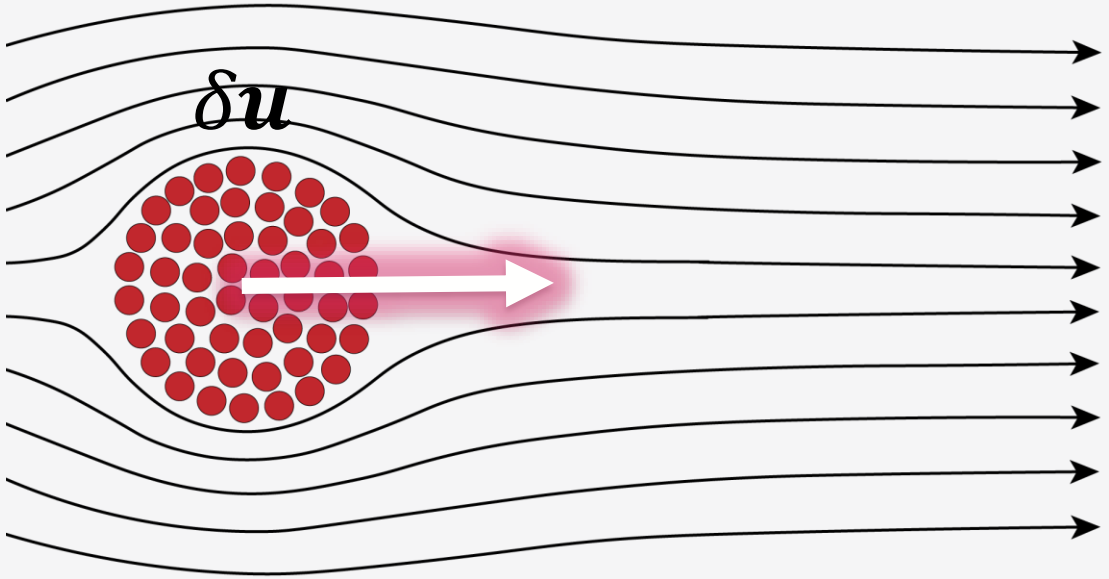
Related to [Daviet & Bertails-Descoubes 2017, Tampubolon et al. 2017]

$$\nabla p = \nabla \cdot \boldsymbol{u}$$



Reversible Pressure Gradient
(Buoyancy)

$$f(\delta \boldsymbol{u}) = A\delta \boldsymbol{u}$$

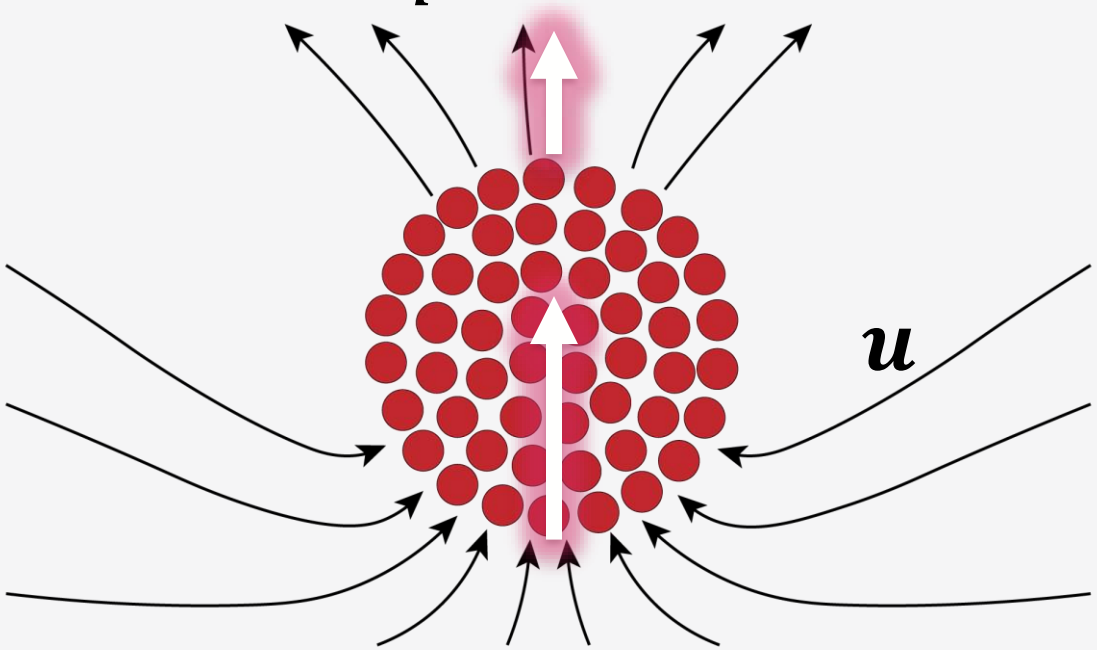


Viscous Drag Force
(Friction)

Hairs and Liquid as a Continuum

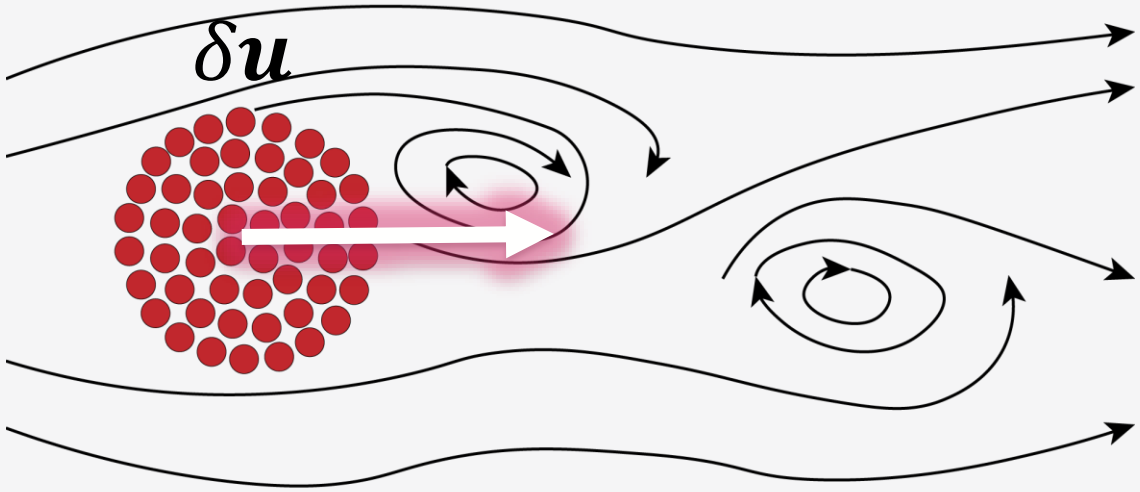
Related to [Daviet & Bertails-Descoubes 2017, Tampubolon et al. 2017]

$$\nabla p = \nabla \cdot \boldsymbol{u}$$



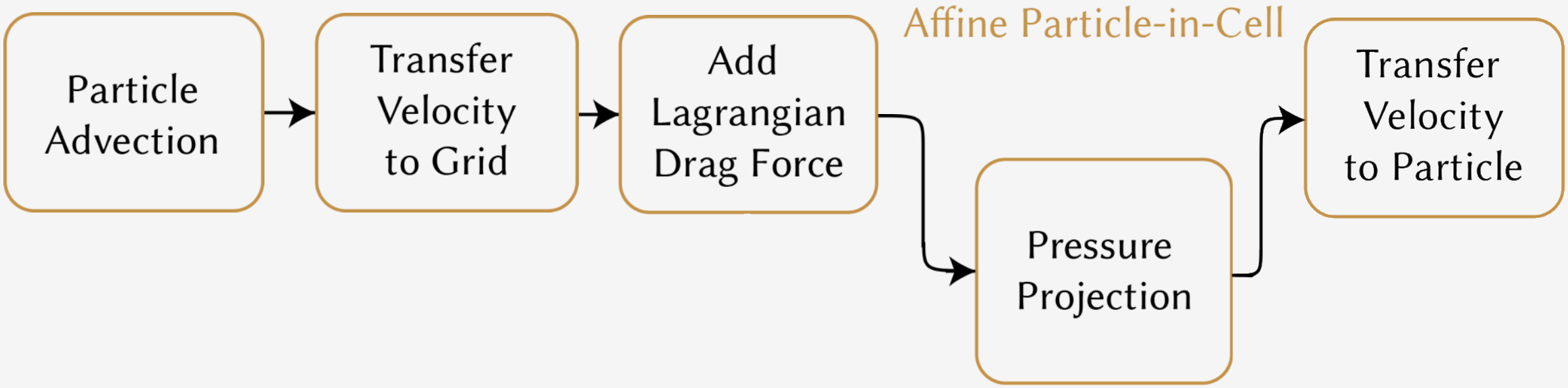
Reversible Pressure Gradient
(Buoyancy)

$$f(\delta \boldsymbol{u}) = A\delta \boldsymbol{u} + B|\delta \boldsymbol{u}|\delta \boldsymbol{u}$$



Quadratic Drag Force
(Friction + Wake Turbulence)

Pipeline

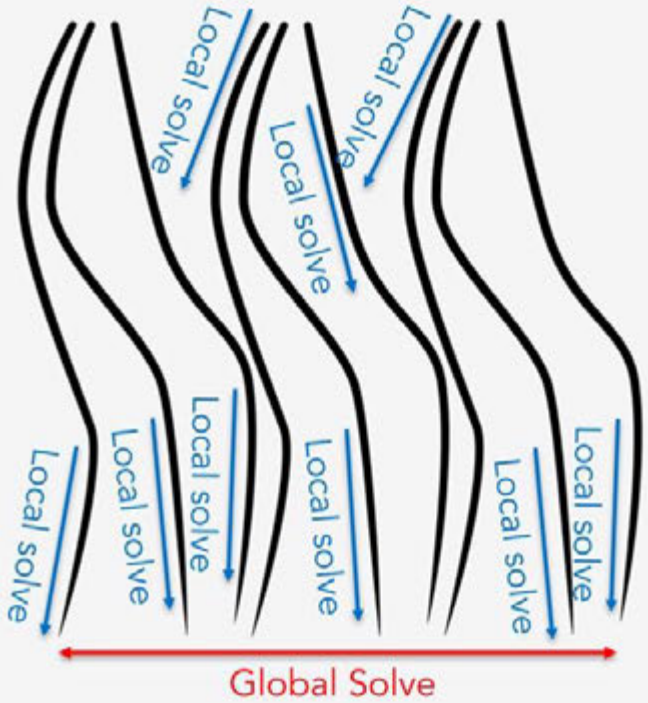


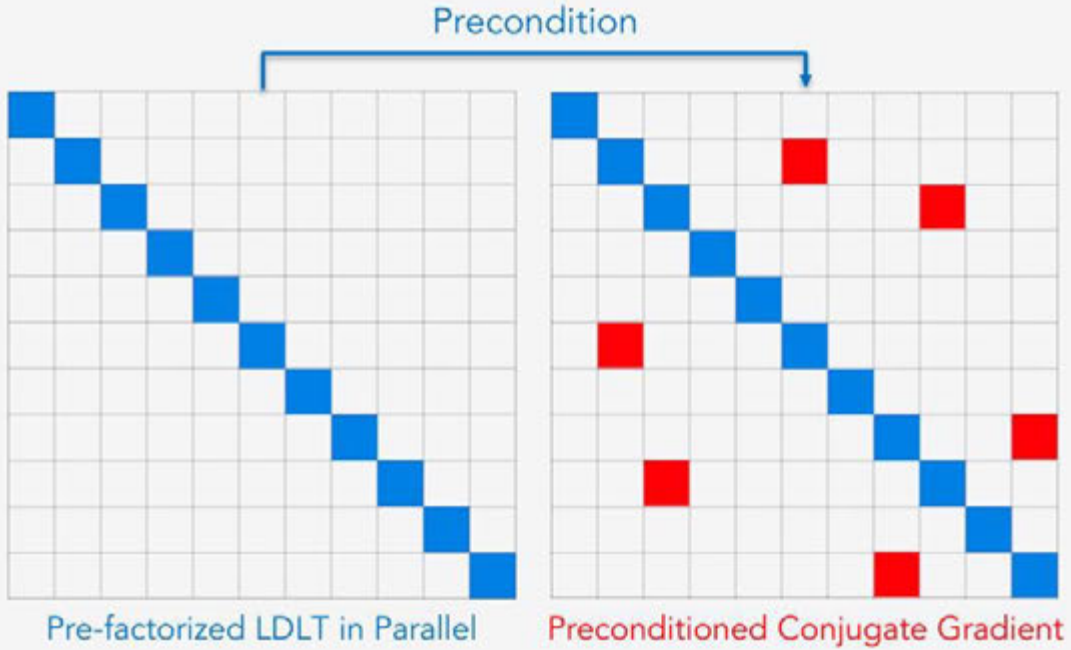
Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipe

Par
Adve

sfer
city
ticle

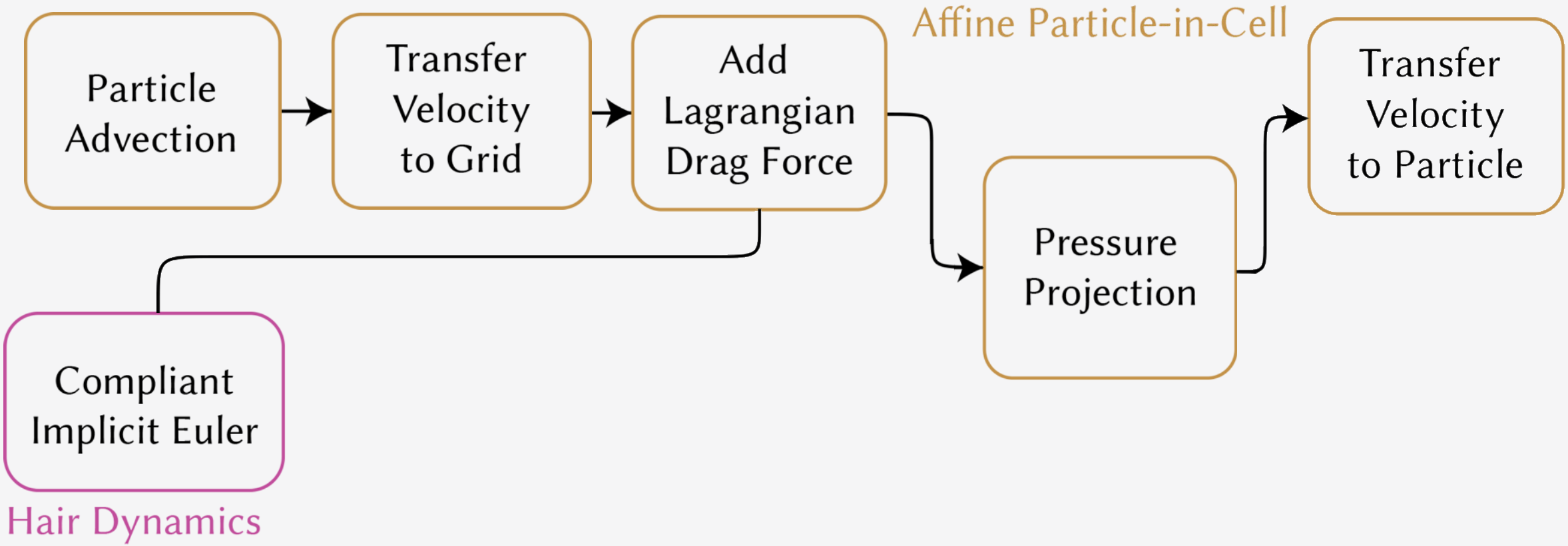




50

Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipeline



Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipe

Par
Adve

sfer
city
rticle

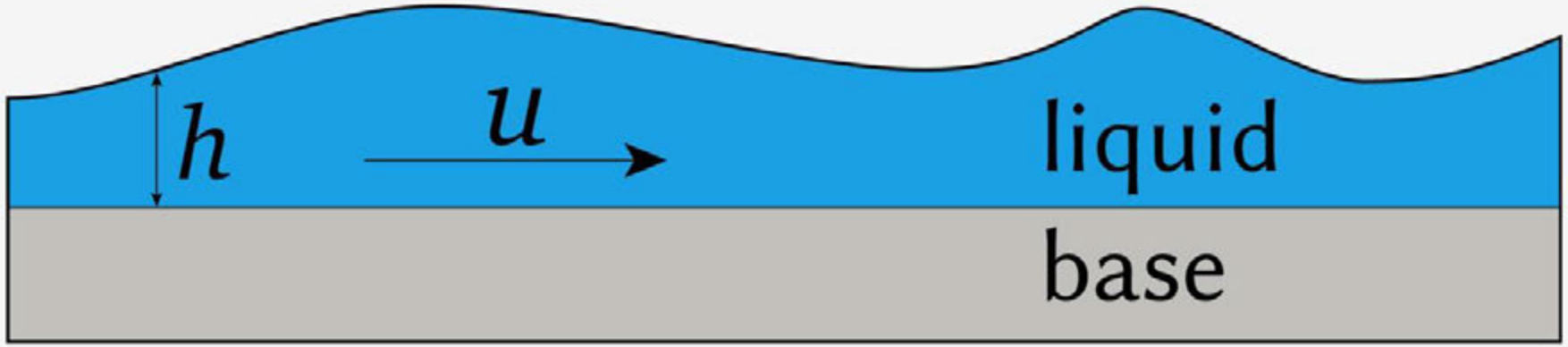
Comp
Implici

Hair Dy

Shallow Water Equation

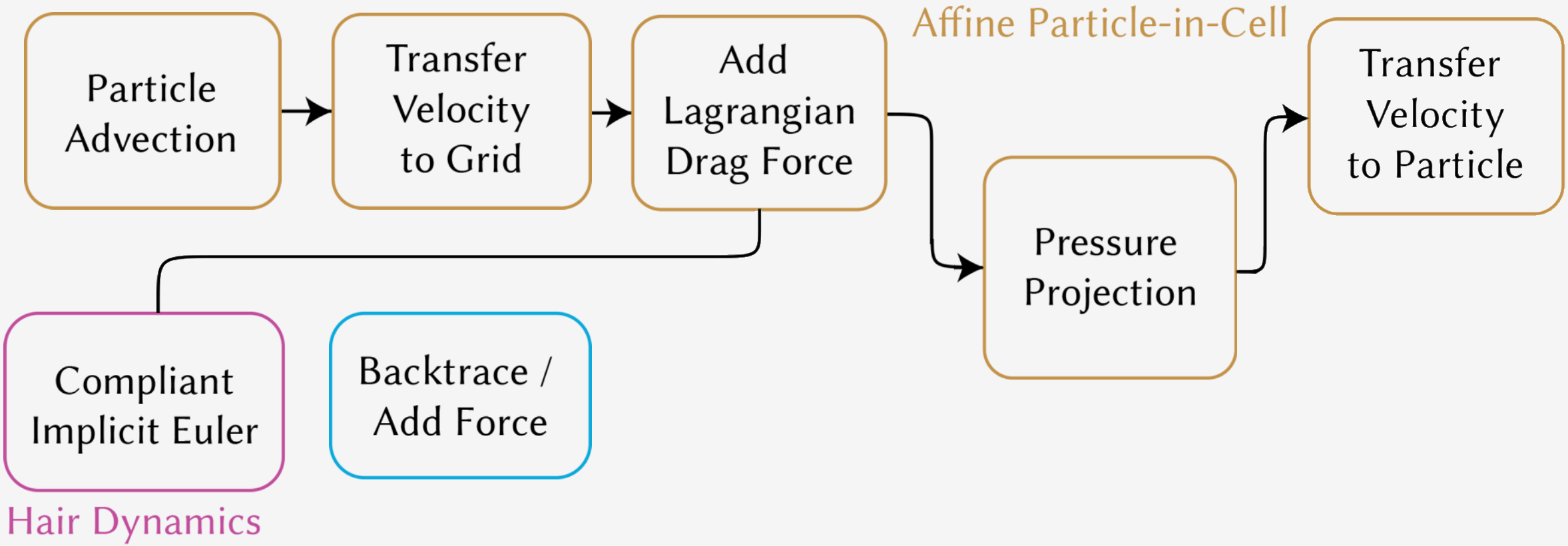
Momentum Equation

$$\underbrace{\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x}}_{\text{✔Inertia}} = \underbrace{-\frac{1}{\rho}\frac{\partial p}{\partial x}}_{\text{✔Surface Tension}} + \underbrace{a_{\text{ext}}}_{\text{✔External Force (Gravity)}}$$



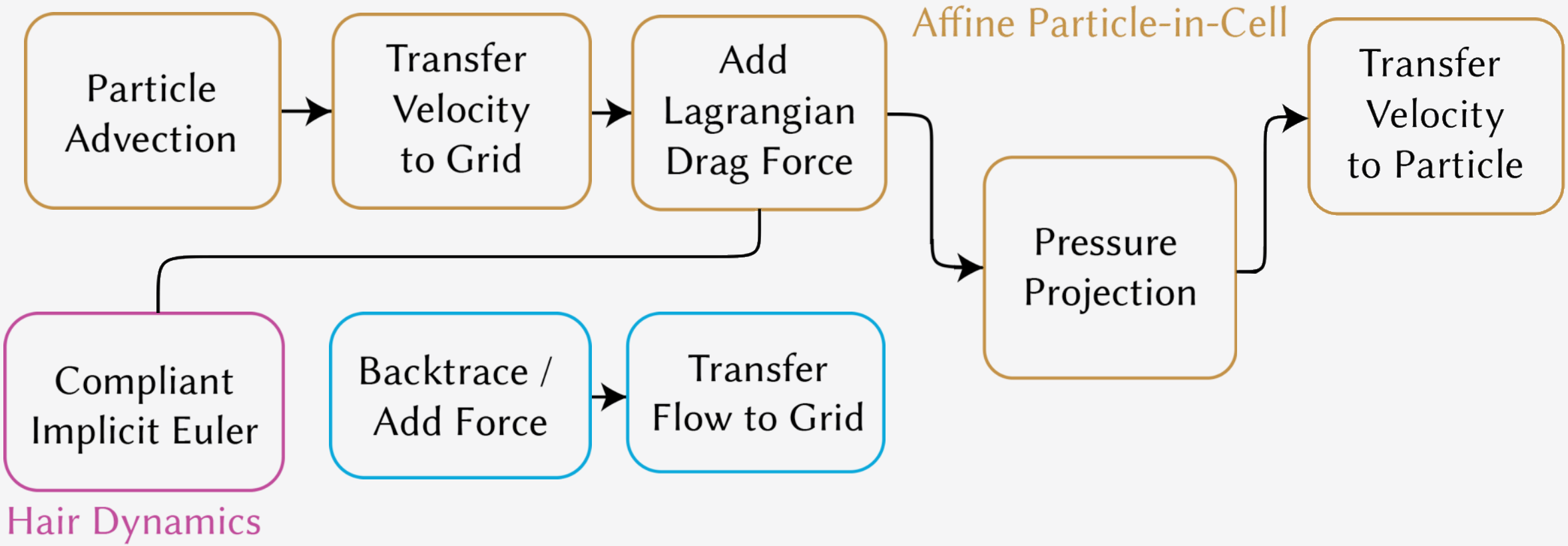
Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipeline



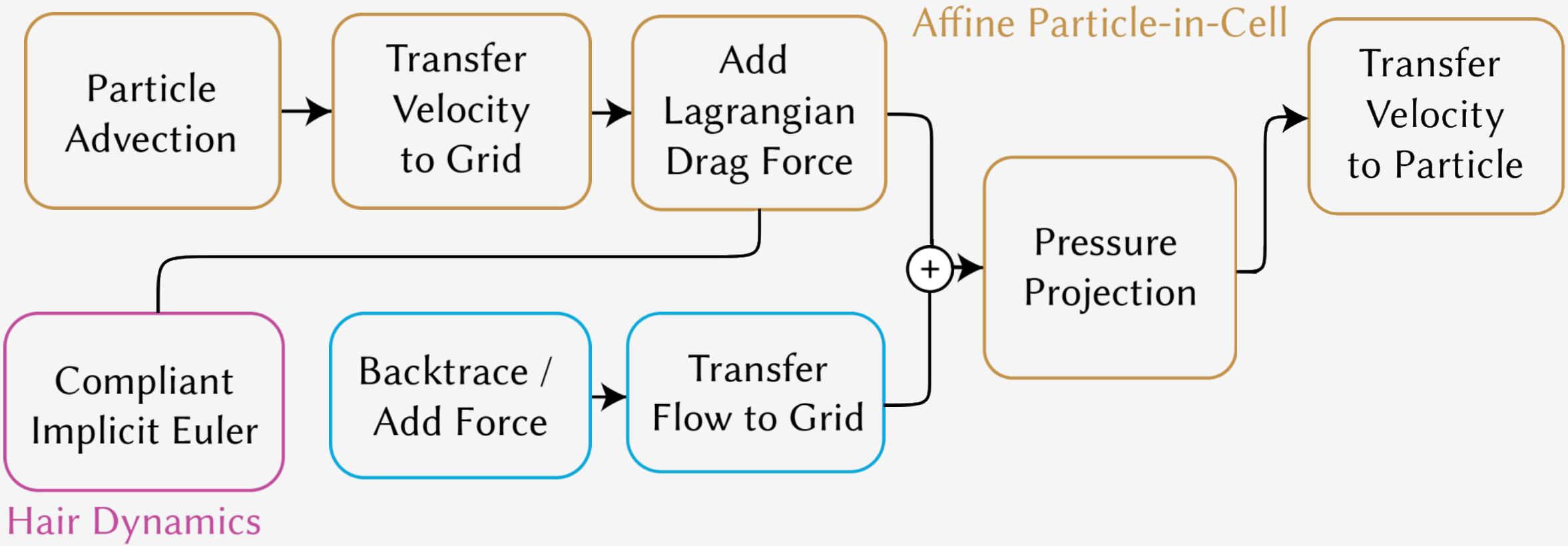
Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipeline



Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipeline



Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipe

Par
Adve

sfer
city
rticle

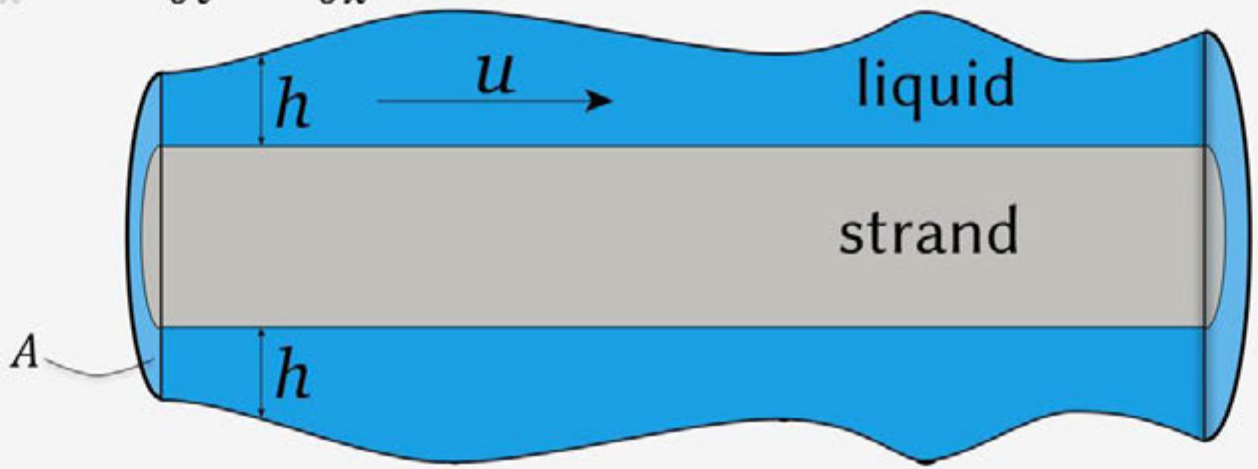
Comp
Implici

Hair Dy

Reduced-Liquid Equation on Hair

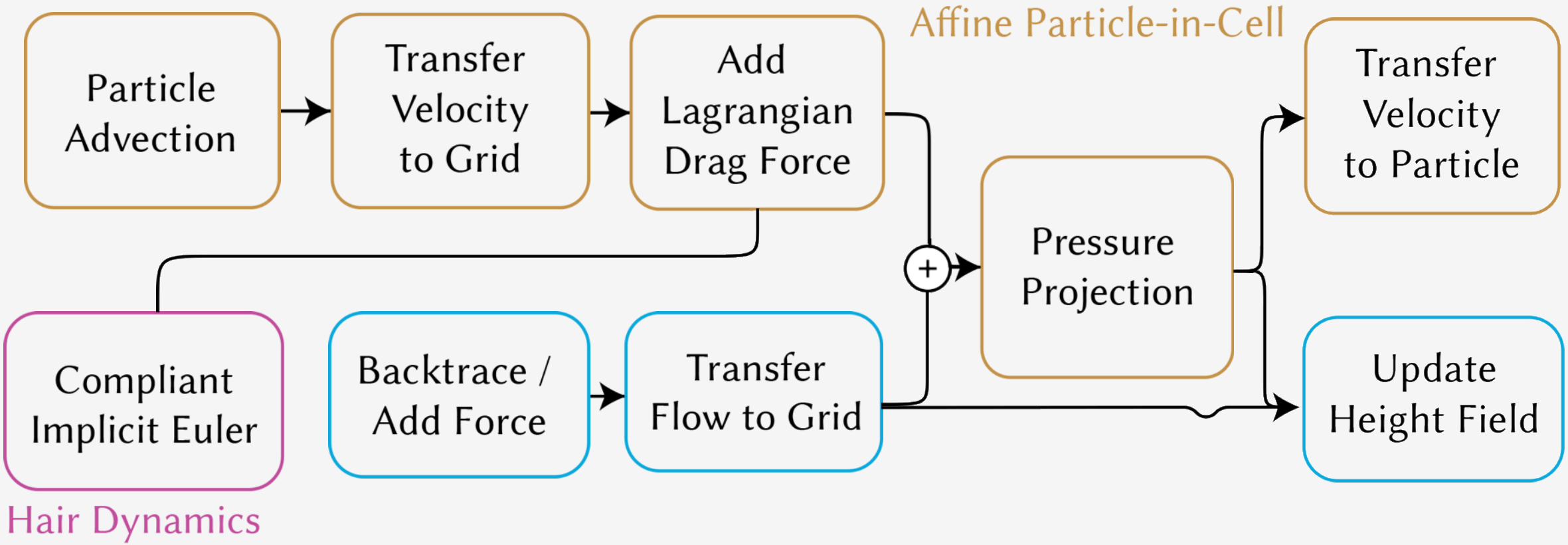
Continuity Equation for Mass

$$\frac{\partial h}{\partial t} + u\frac{\partial h}{\partial x} = 0 \qquad \frac{\partial A}{\partial t} + u\frac{\partial A}{\partial x} = 0$$



Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

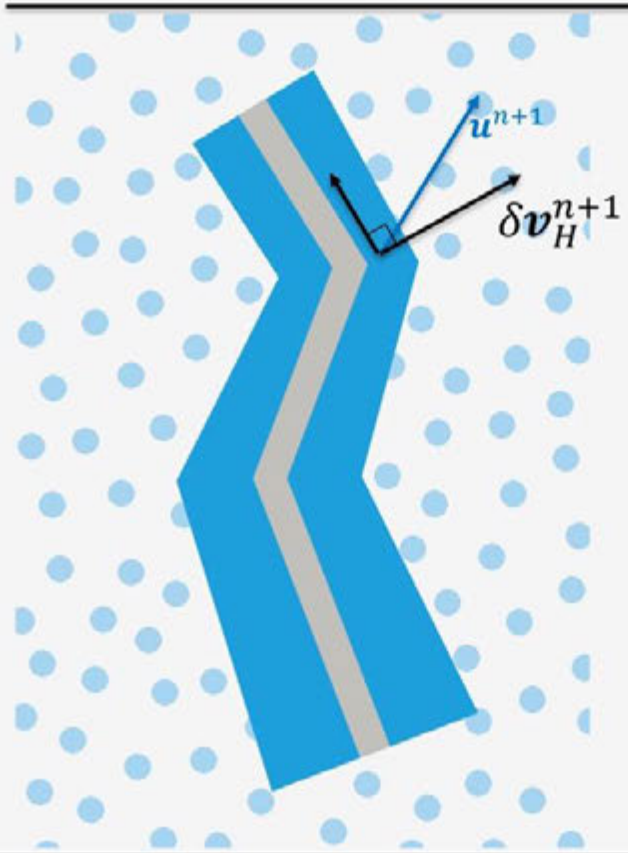
Pipeline



Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipe

Capturing Reduced-Liquid



New Volume ← Original + Gathered

New Momentum ← Hair + Reduced + Gathered

New Mass ← Original + Gathered

New Velocity ← Original + Gathered

Part
Adve

sfer
city
ticle

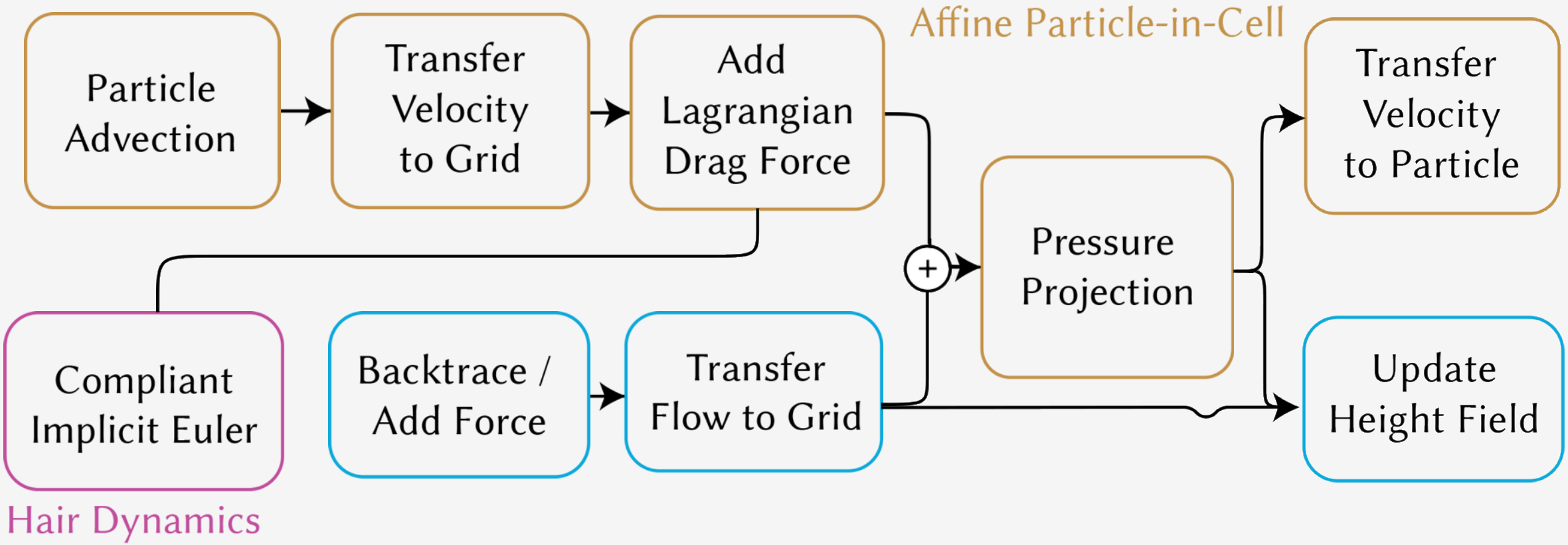
Comp
Implici

ate
Field

Hair Dy

Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

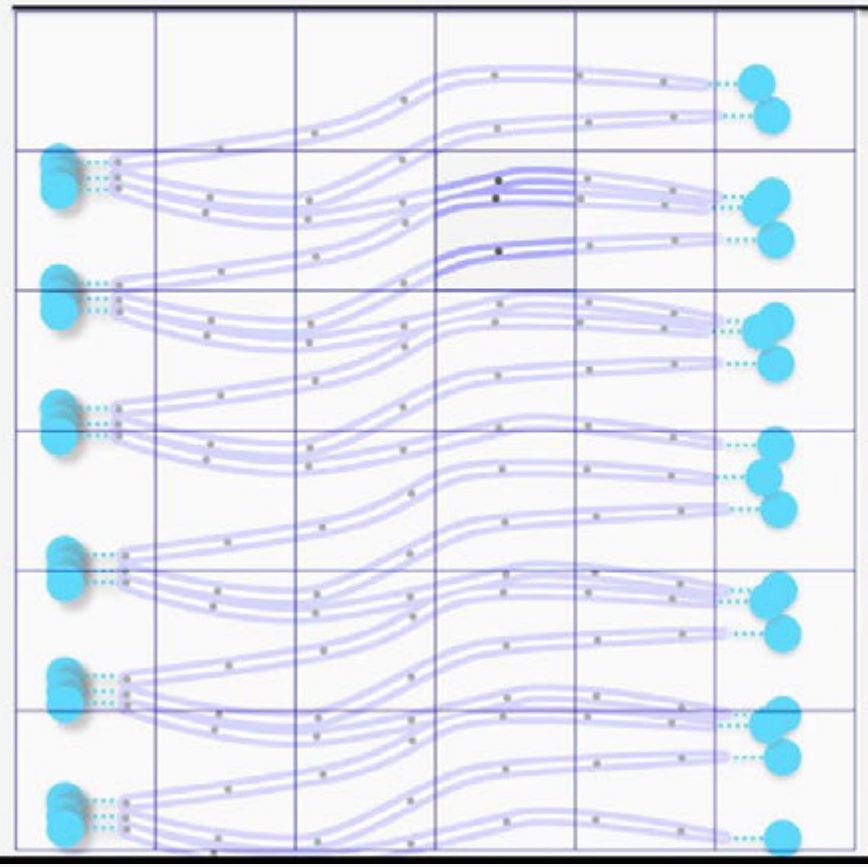
Pipeline

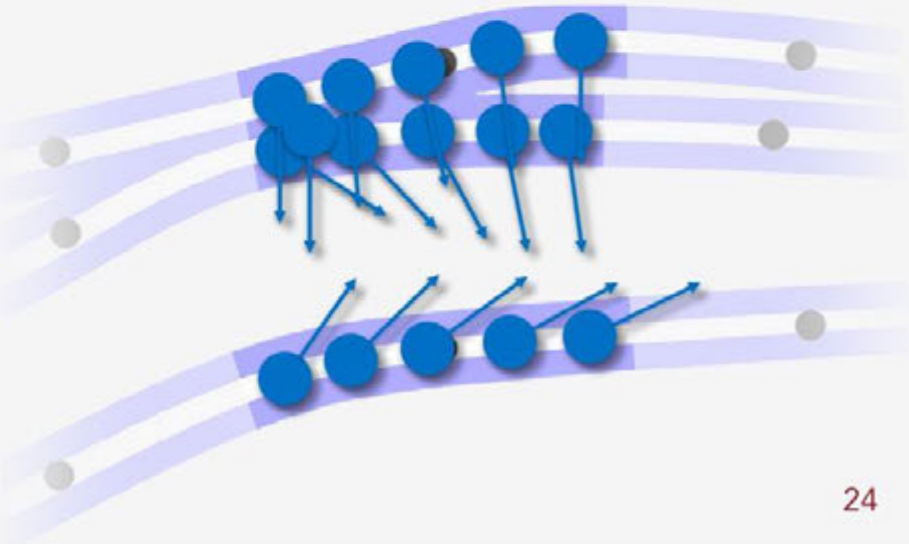


Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipe

Dripping of Reduced-Liquid





24

Par
Adve

sfer
city
ticle

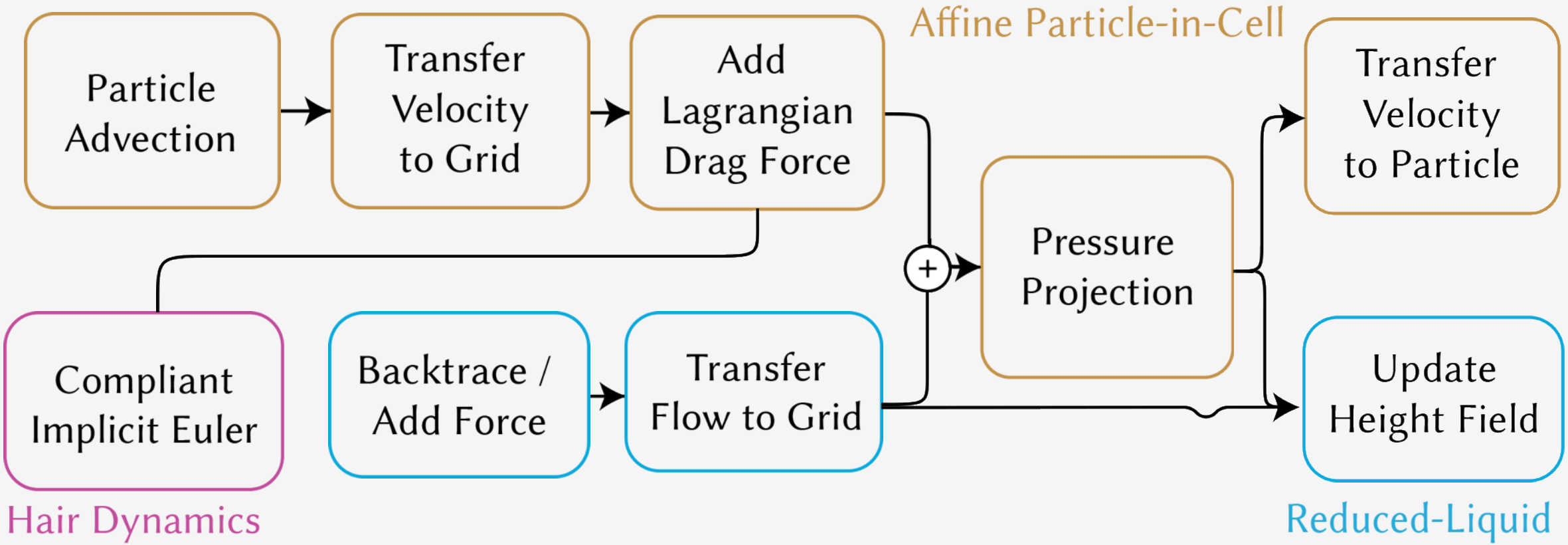
Comp
Implici

ate
Field

Hair Dy

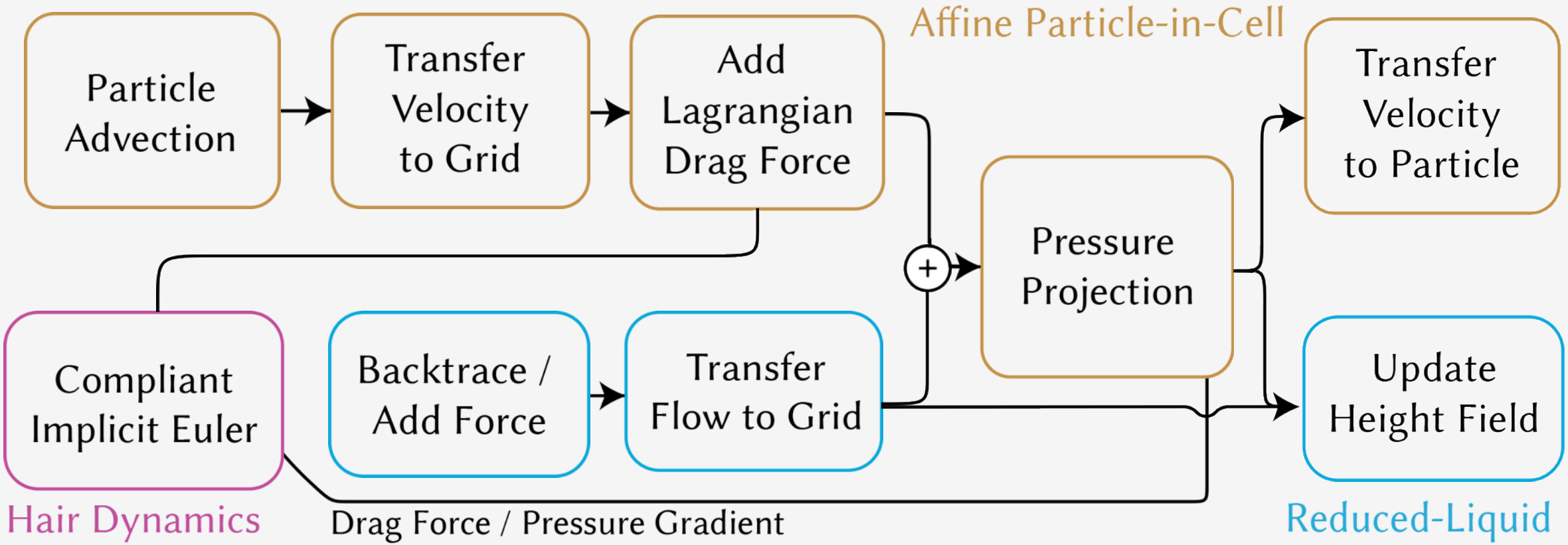
Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipeline

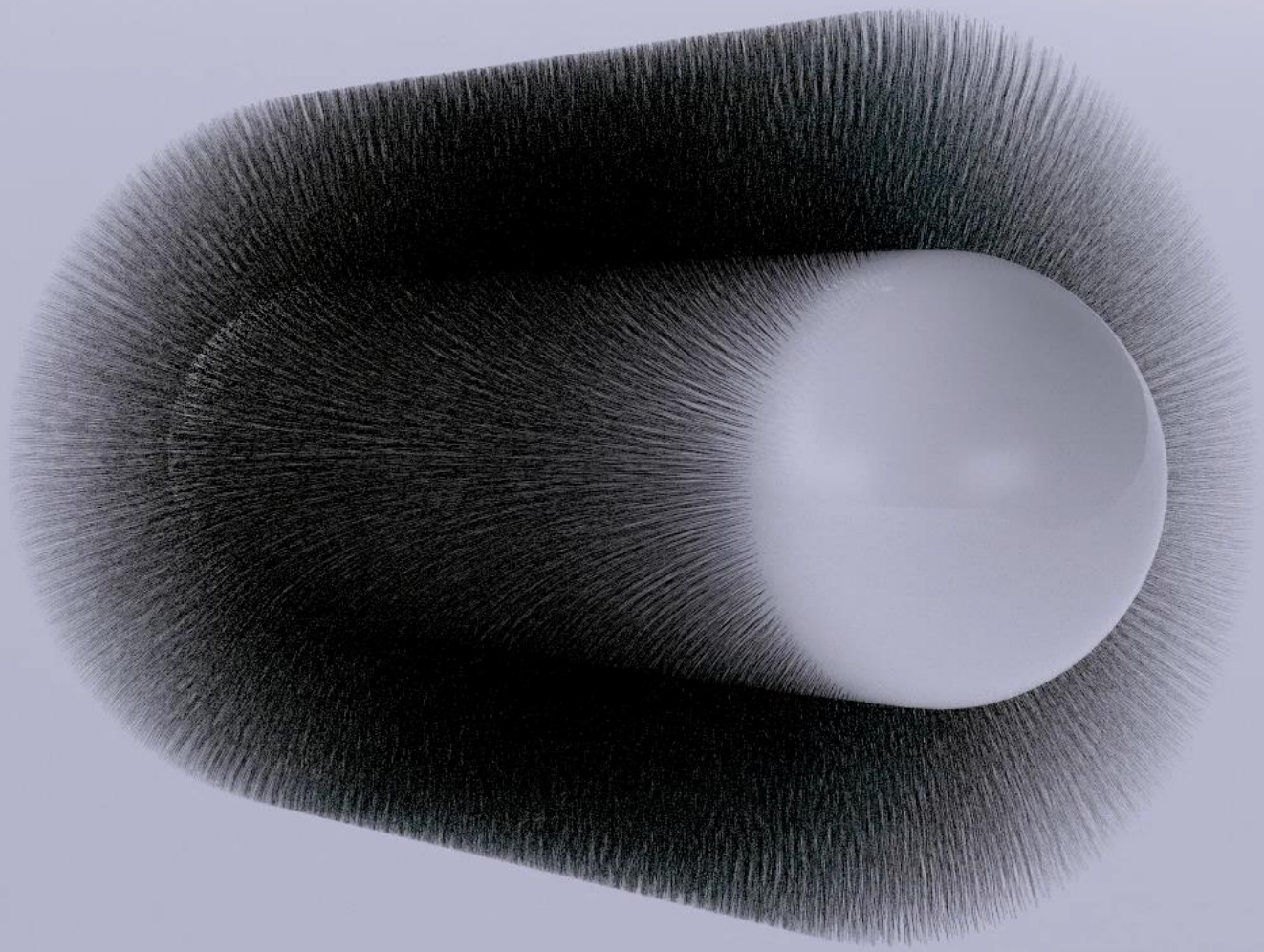


Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.

Pipeline



Chenfanfu Jiang, Craig Schroeder, and Joseph Teran. "An angular momentum conserving affine-particle-in-cell method." *Journal of Computational Physics* 338 (2017): 137-164.



Timing

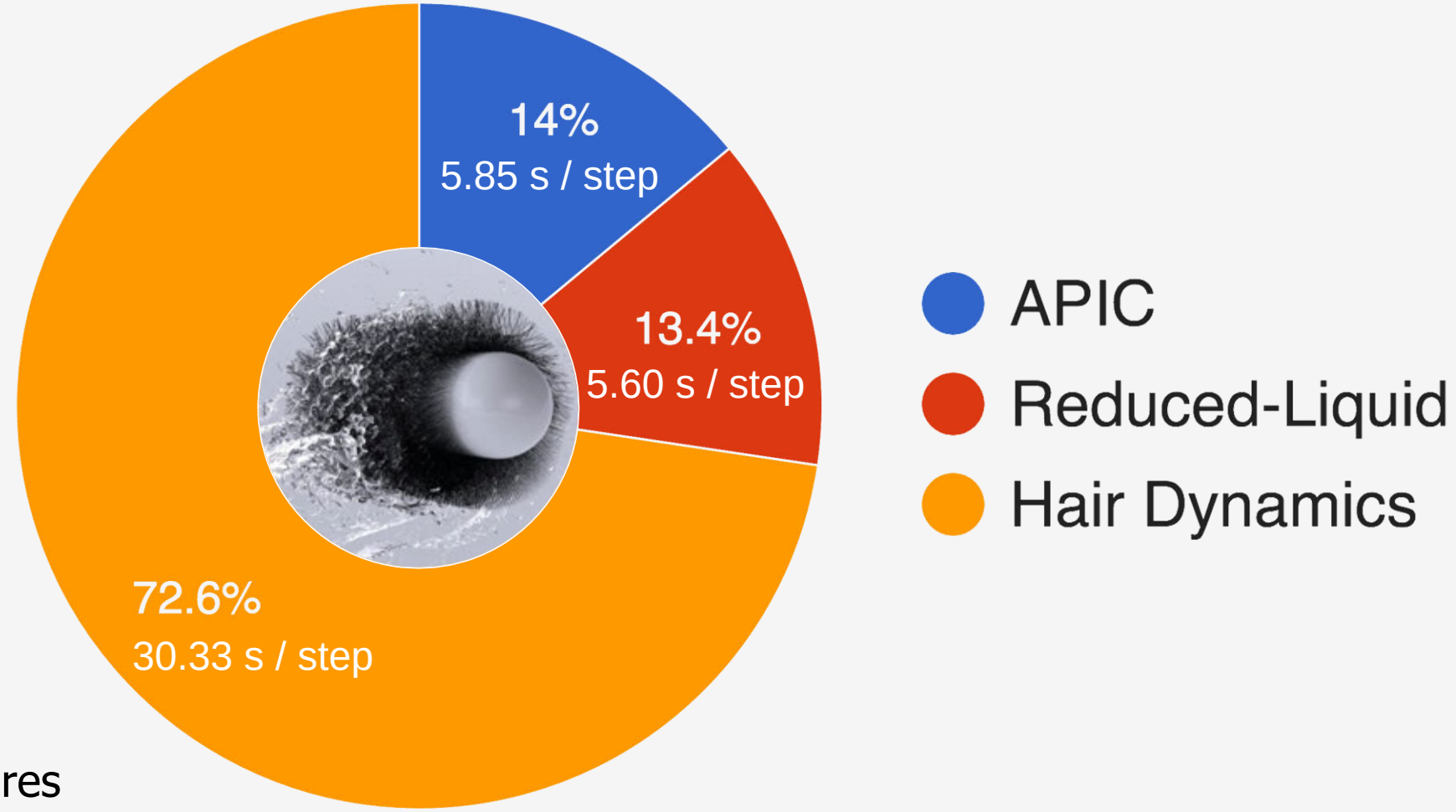
Hairs
32,768 strands
63 DoFs / strand

Grid Res
128x128x256

Time Step
0.003 s

Computational Time / Step
41.78 s

Xeon E5-2687W x 32 cores



Future Work

Quantitative validation w. r. t. real world.

More effective surface reconstruction.

Extension for hair skinning.

Future Work

Quantitative validation w. r. t. real world.

More effective surface reconstruction.

Extension for hair skinning.

Future Work

Quantitative validation w. r. t. real world.

More effective surface reconstruction.

Extension for hair skinning.

Future Work

Quantitative validation w. r. t. real world.

More effective surface reconstruction.

Extension for hair skinning.

Executables & Code

http://libwethair.info

Acknowledgements

Peter Yichen Chen
Ryan Goldade
Xinxin Zhang
Fang Da
Bo Zhu

Daisy Nyugen
Derrick Lim
Cristin Barghiel
Monika Janek
Silvina Rocca

NSF Grant Nos.: 1409286, 1319483, 1453101
Graduate Student Research Fellowship No. DGE-16-44869
Natural Sciences and Engineering Research Council of Canada
Grant No. RGPIN-04360-2014
National GEM Consortium, Pixar, and Adobe

Surface Reconstruction / Rendering: Houdini
Tree Structure Experiment

Bico, José, et al. "Adhesion: elastocapillary coalescence in wet hair." *Nature,* 432.7018 (2004): 690-690.