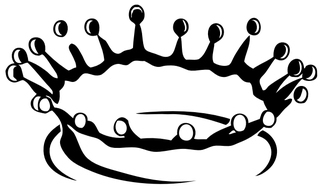
Settling chiral particles in turbulent flow

Mees Flapper, John Sader,
Detlef Lohse & Sander Huisman



Physics of Fluids

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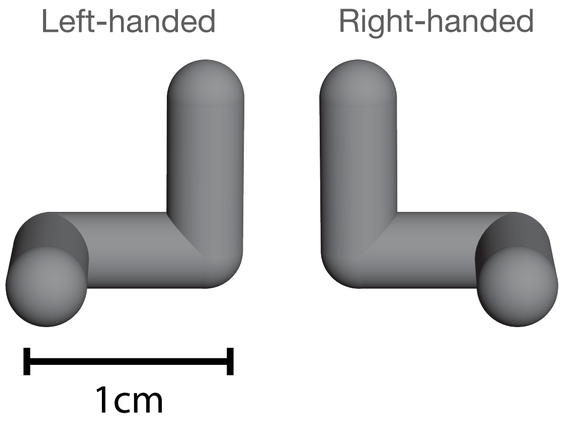
Chiral particles

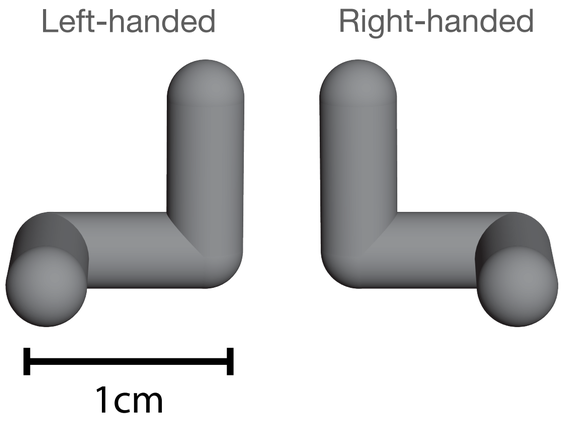
Lentink et al. *Science* 324.5933 (2009)

Chiral particles



Chiral particles: break mirror symmetry

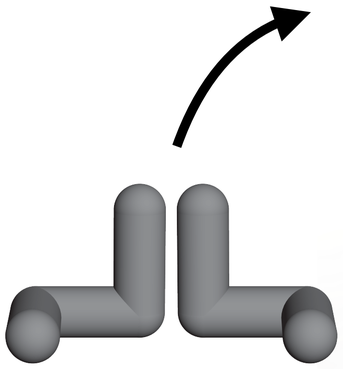
Chiral particles



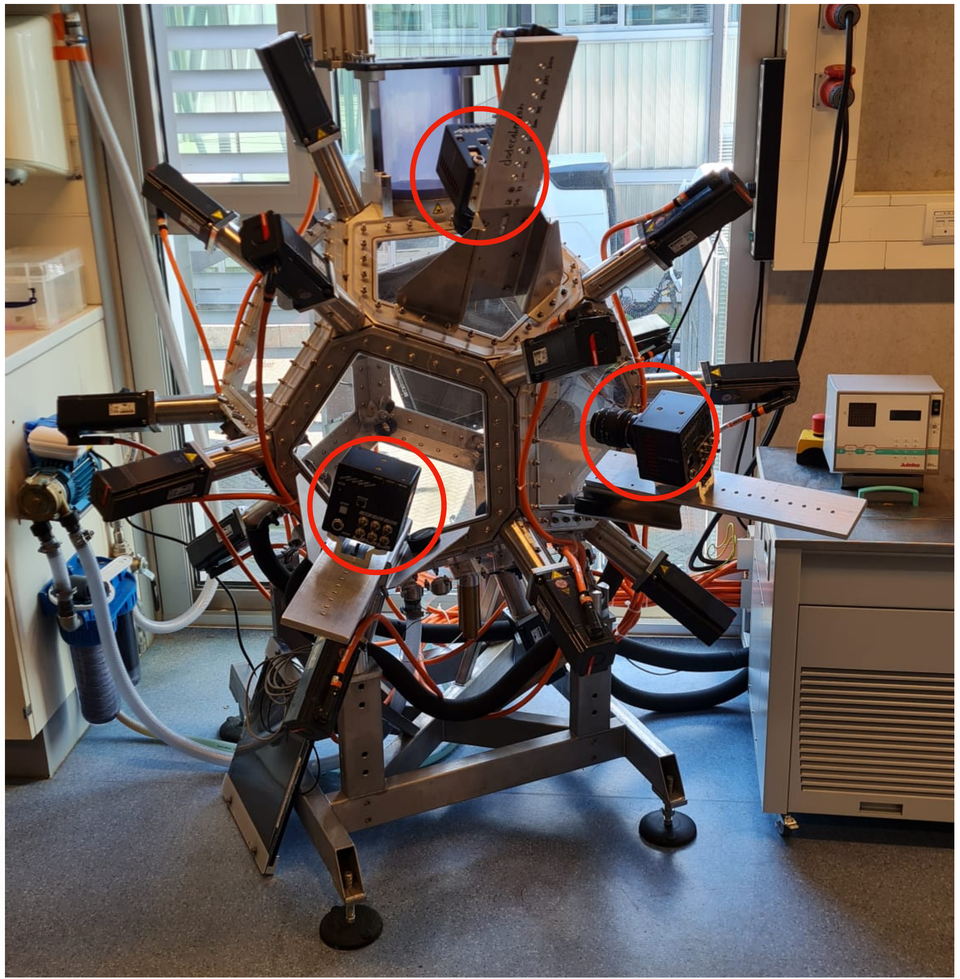
Chiral particles: break mirror symmetry

Chiral particles

How can we find the orientation of particles?



Plastic particles



Chiral particles

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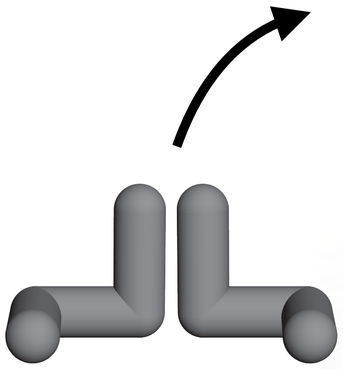
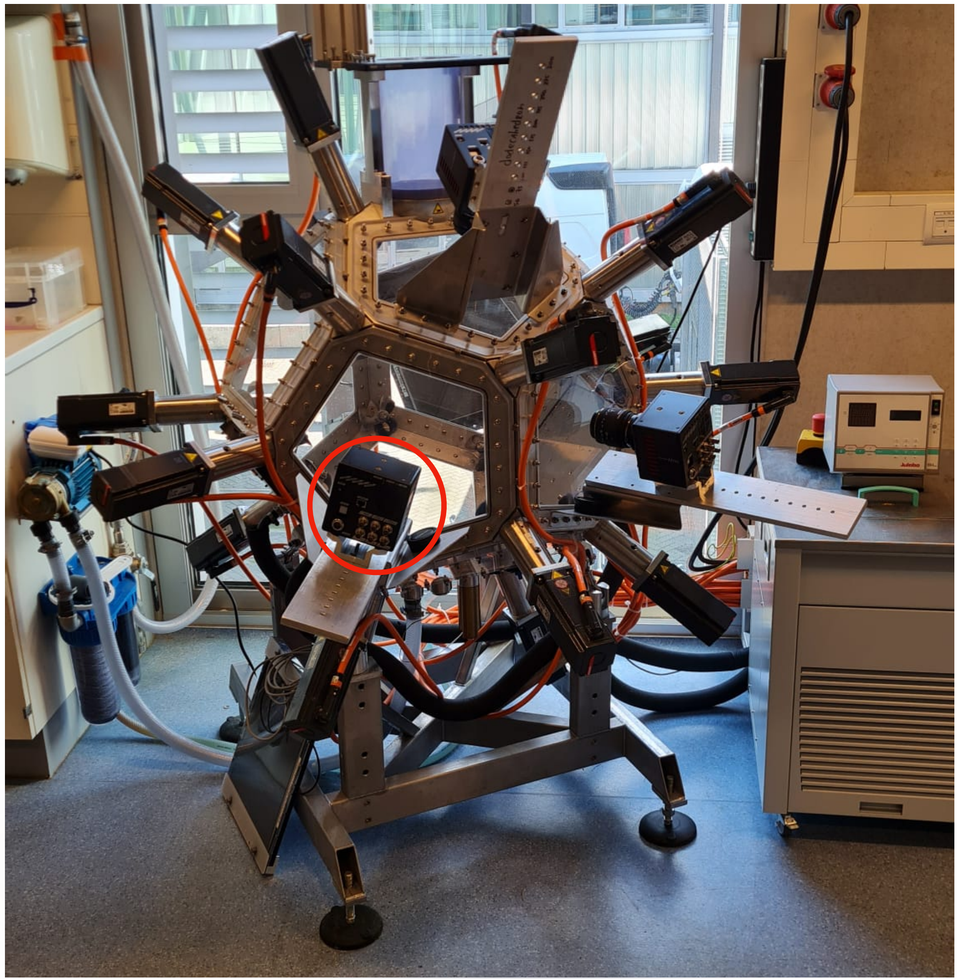
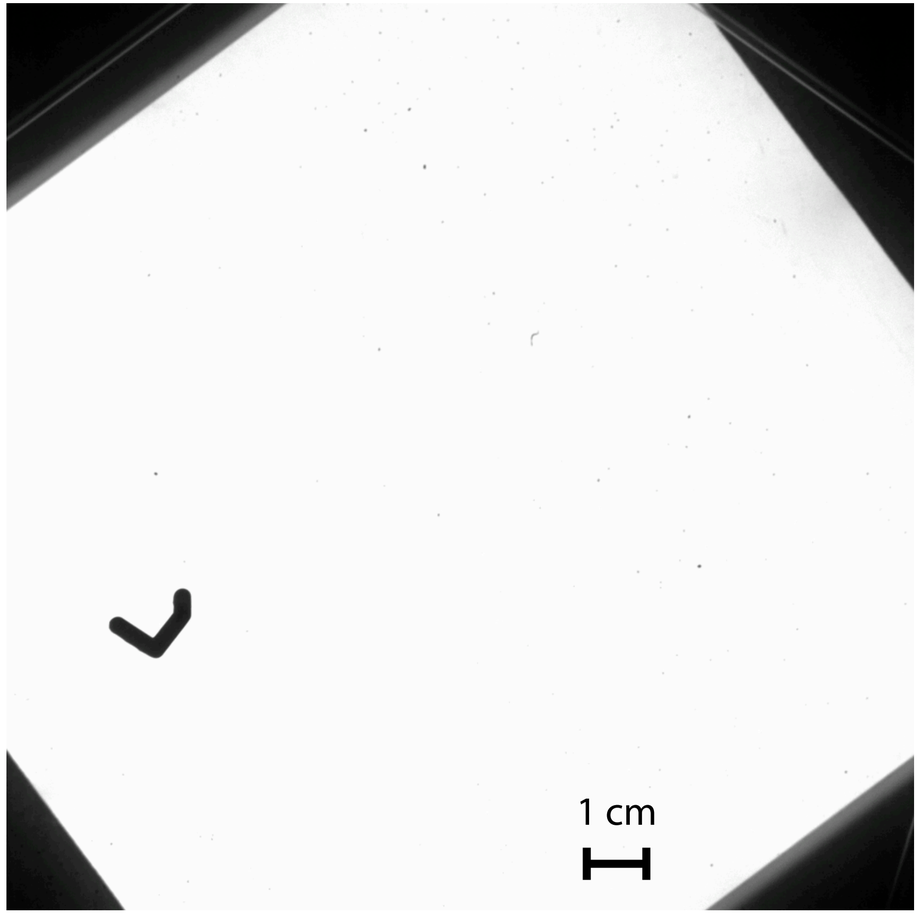


Plastic particles





Chiral particles

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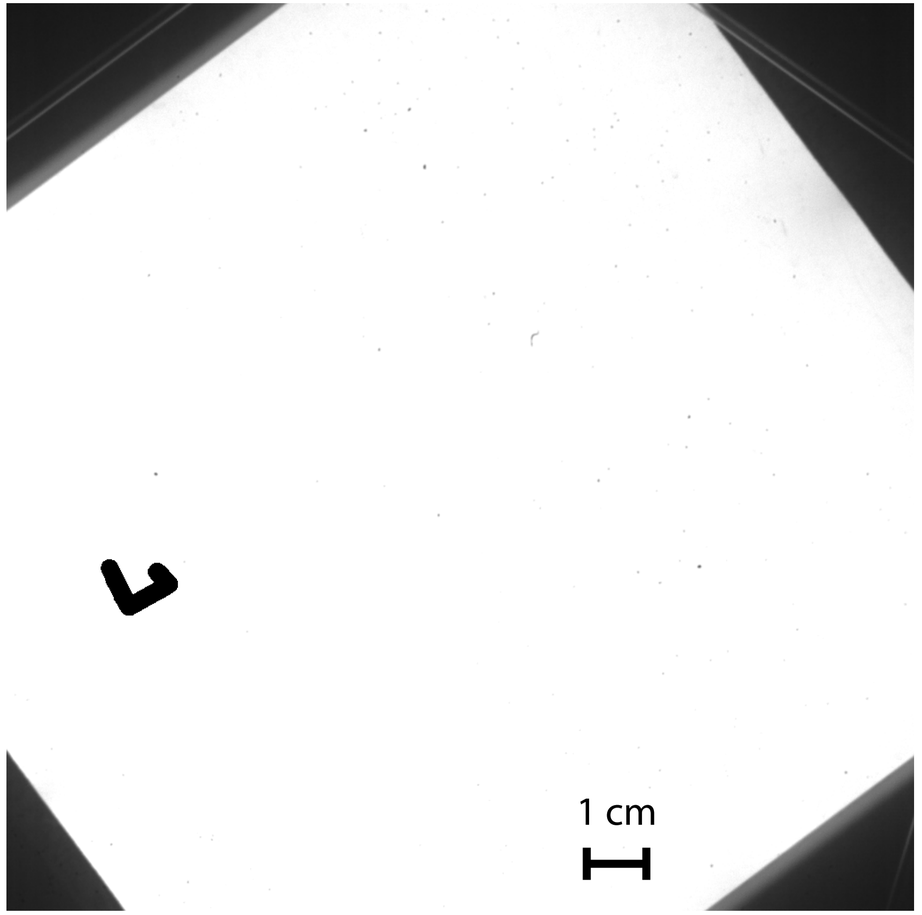
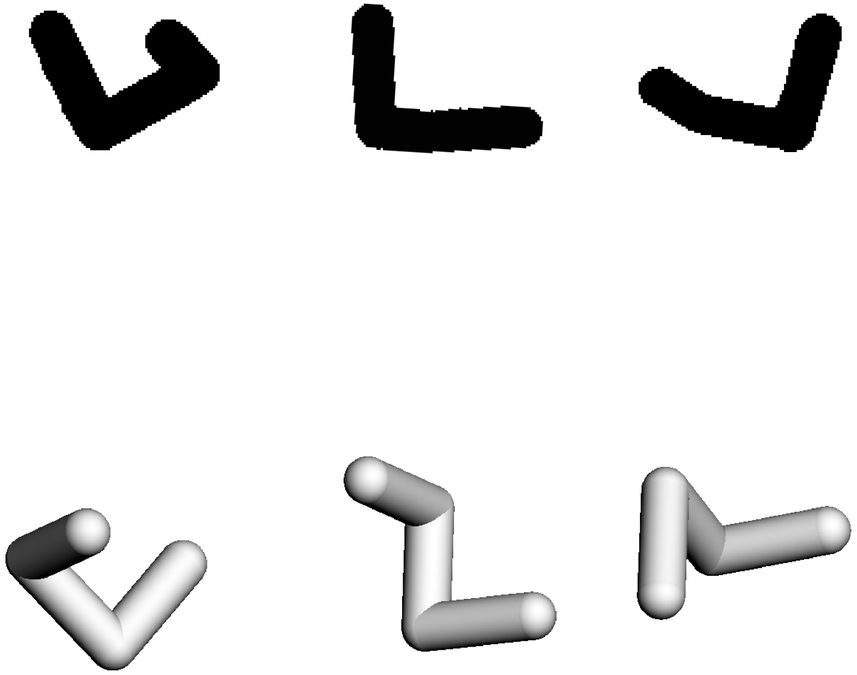


M.M. Flapper, E. Bernard, and S.G. Huisman
Rev. Sci. Instrum. 96, 065207 (2025)

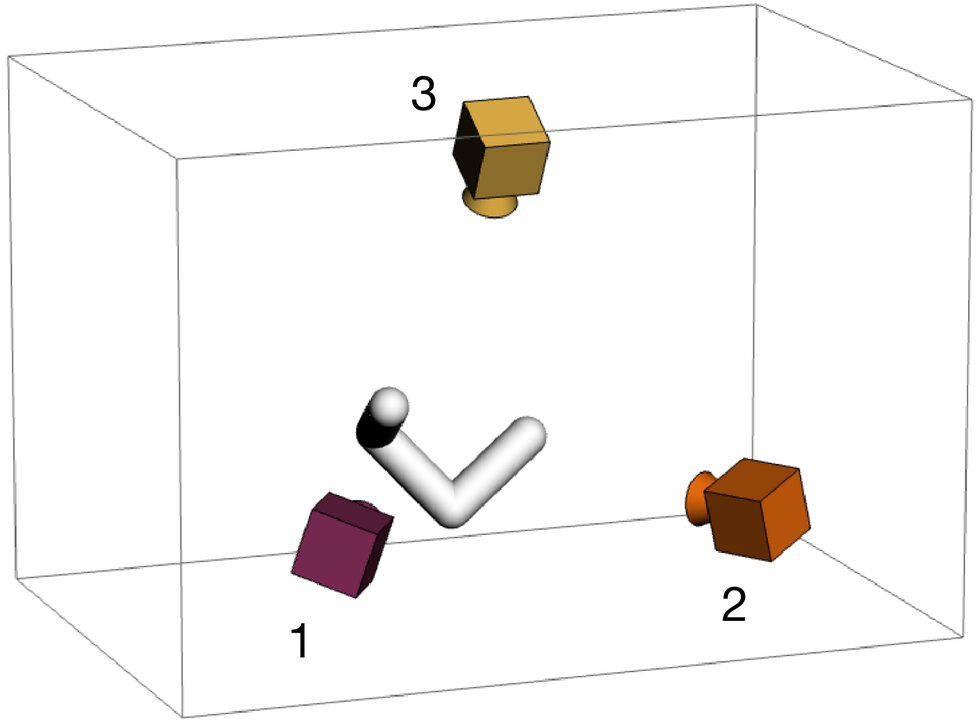
Chiral particles

How can we find the orientation of particles?

Camera 1 Camera 2 Camera 3



Computer generated projections



Computer generated particle

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Chiral particles

How can we find the orientation of particles?

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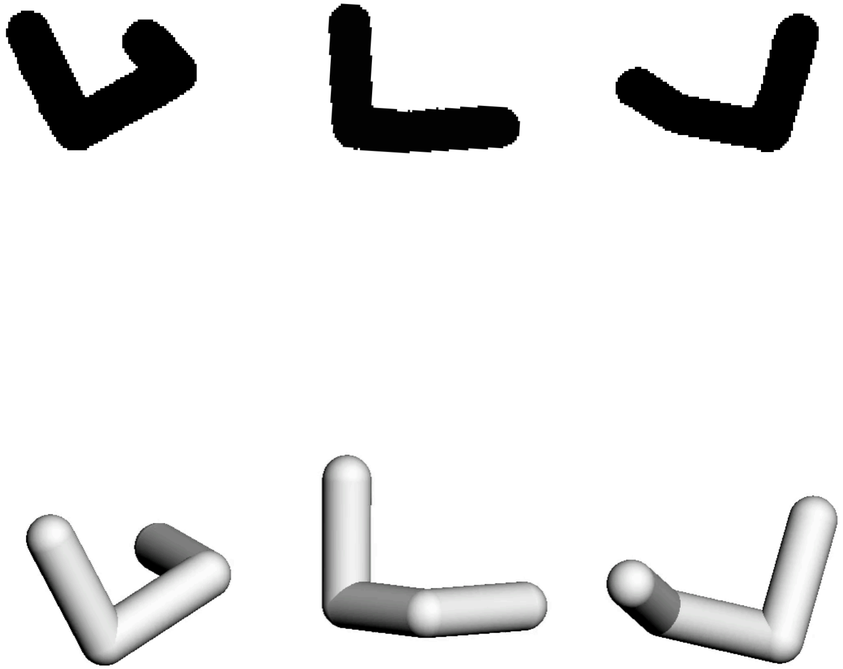
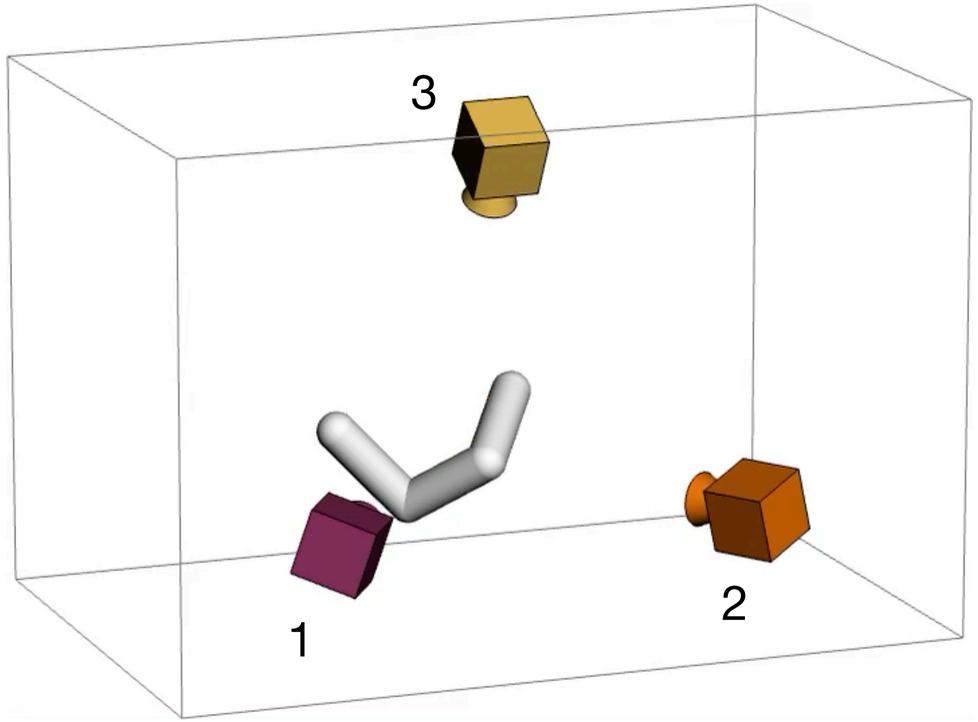


Computer generated projections



Computer generated particle

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Rev. Sci. Instrum. 96, 065207 (2025)

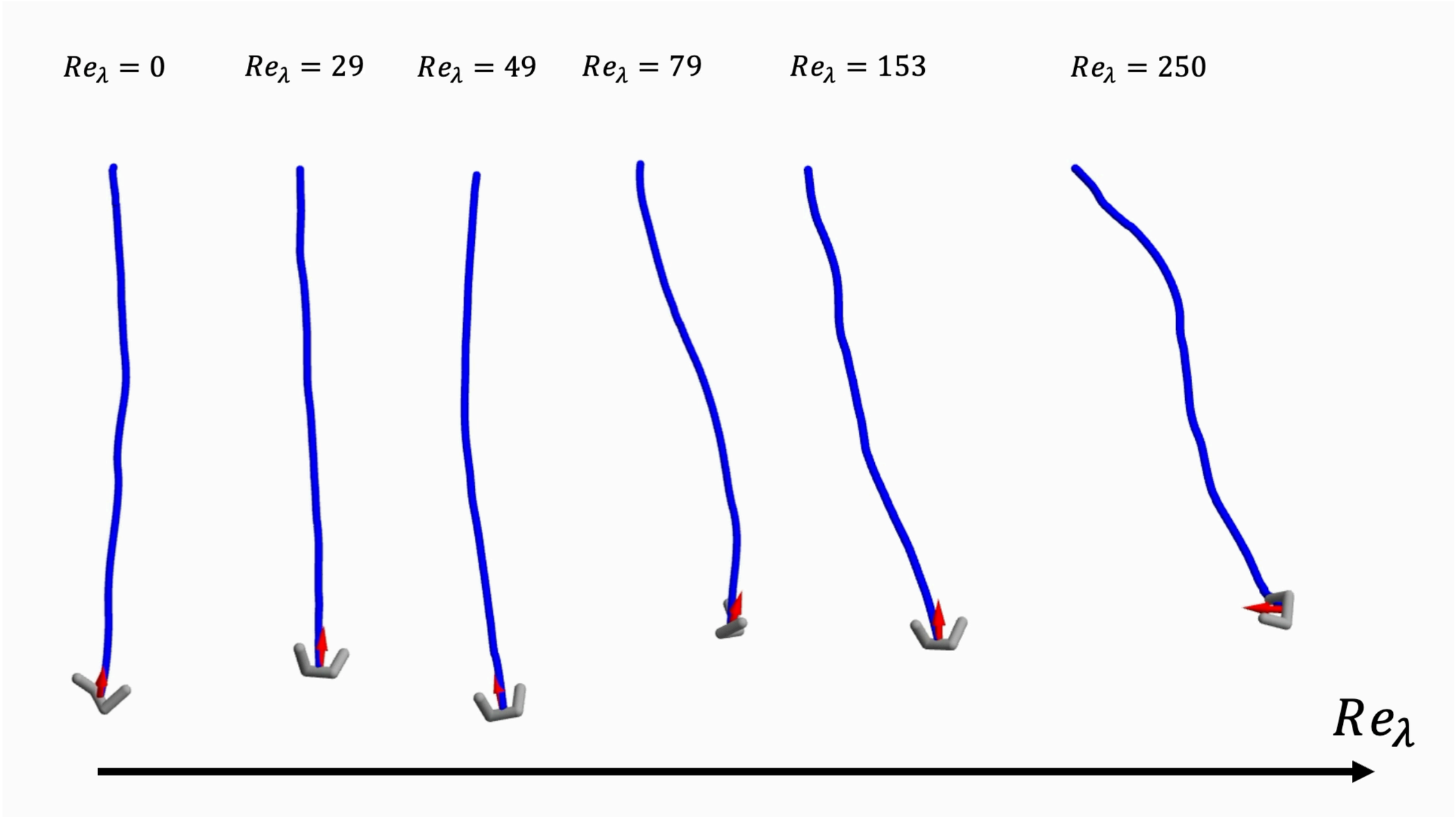
Chiral particles

How can we find the orientation of particles?

Camera recording

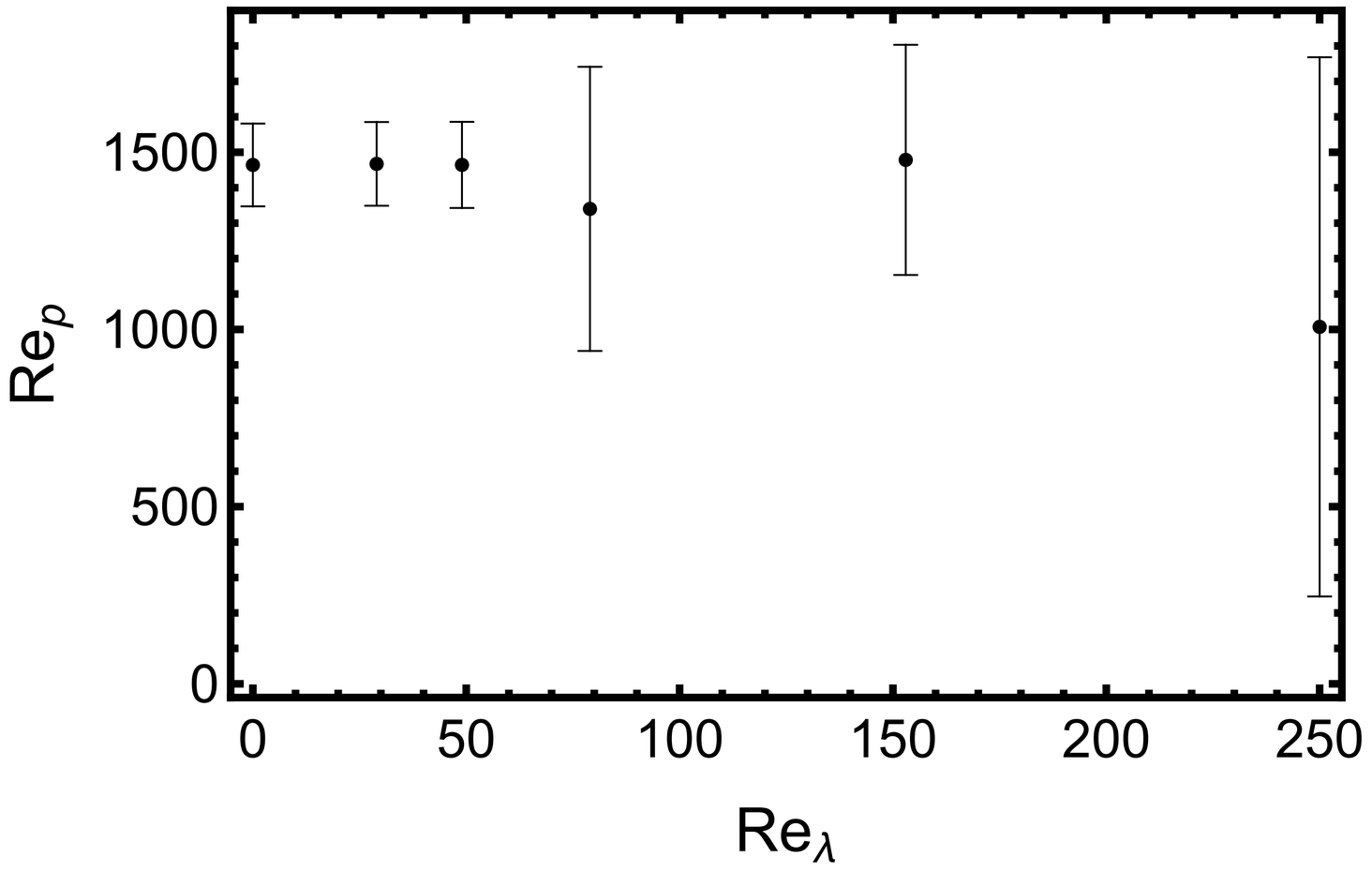
Reconstruction

Results (left-handed particles)



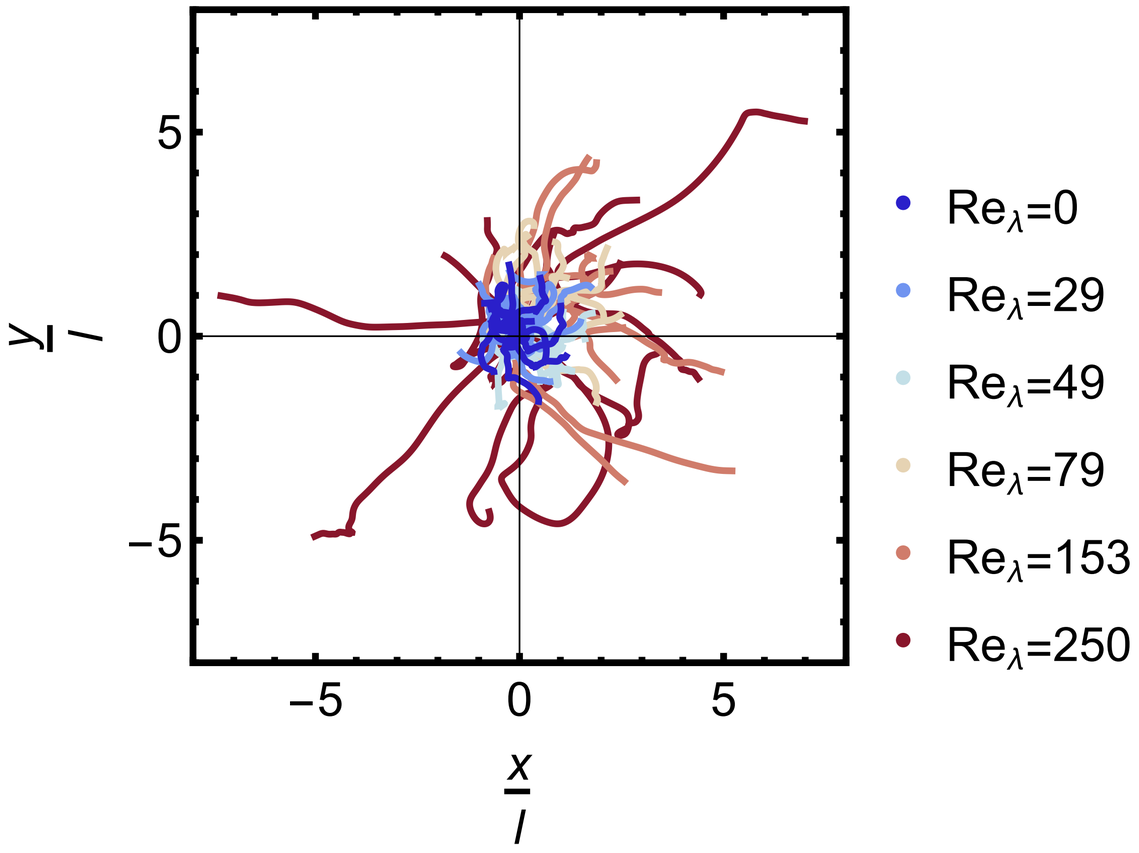
Particle Reynolds number

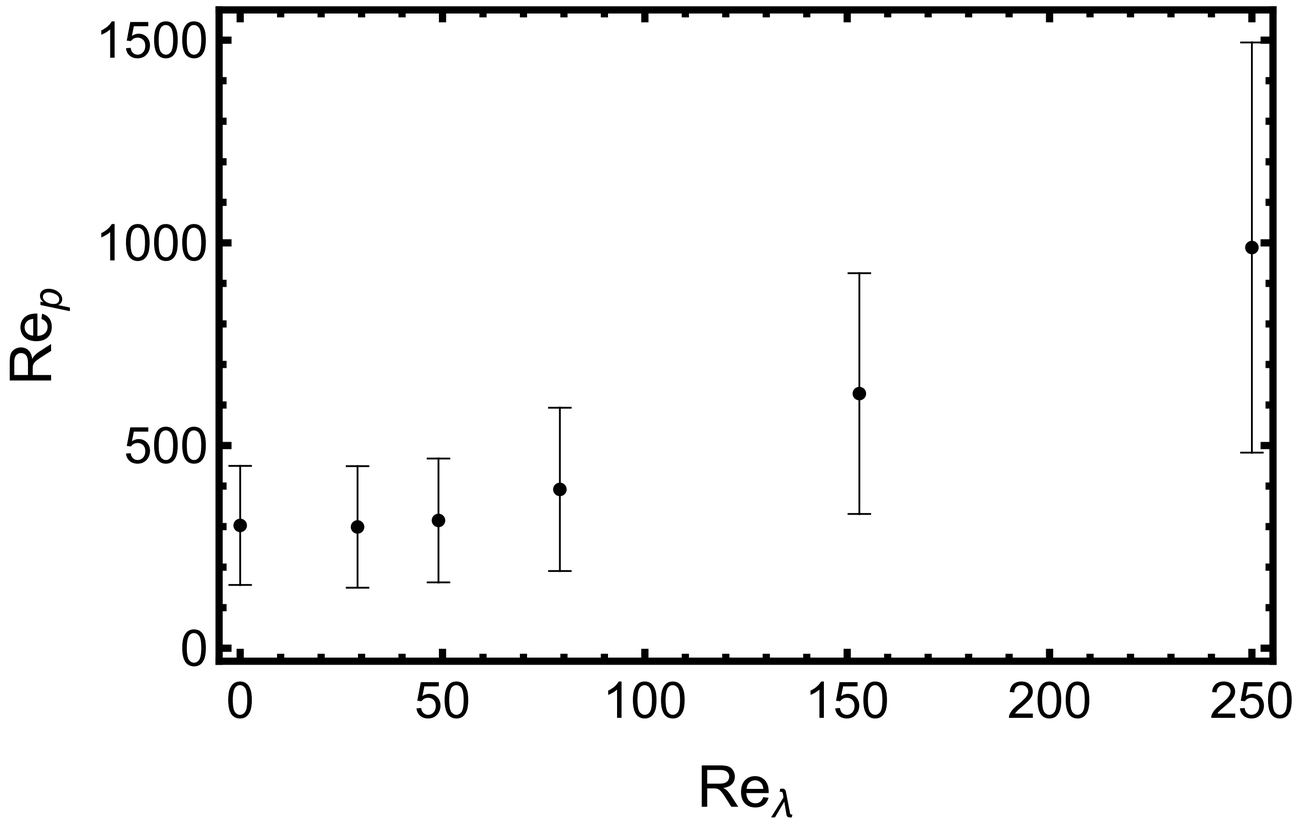
Settling velocity (vertical direction only)



Particle Reynolds number

Planar velocity and trajectory

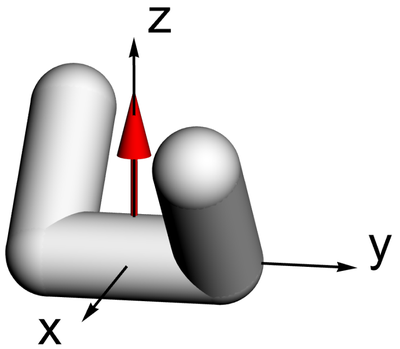


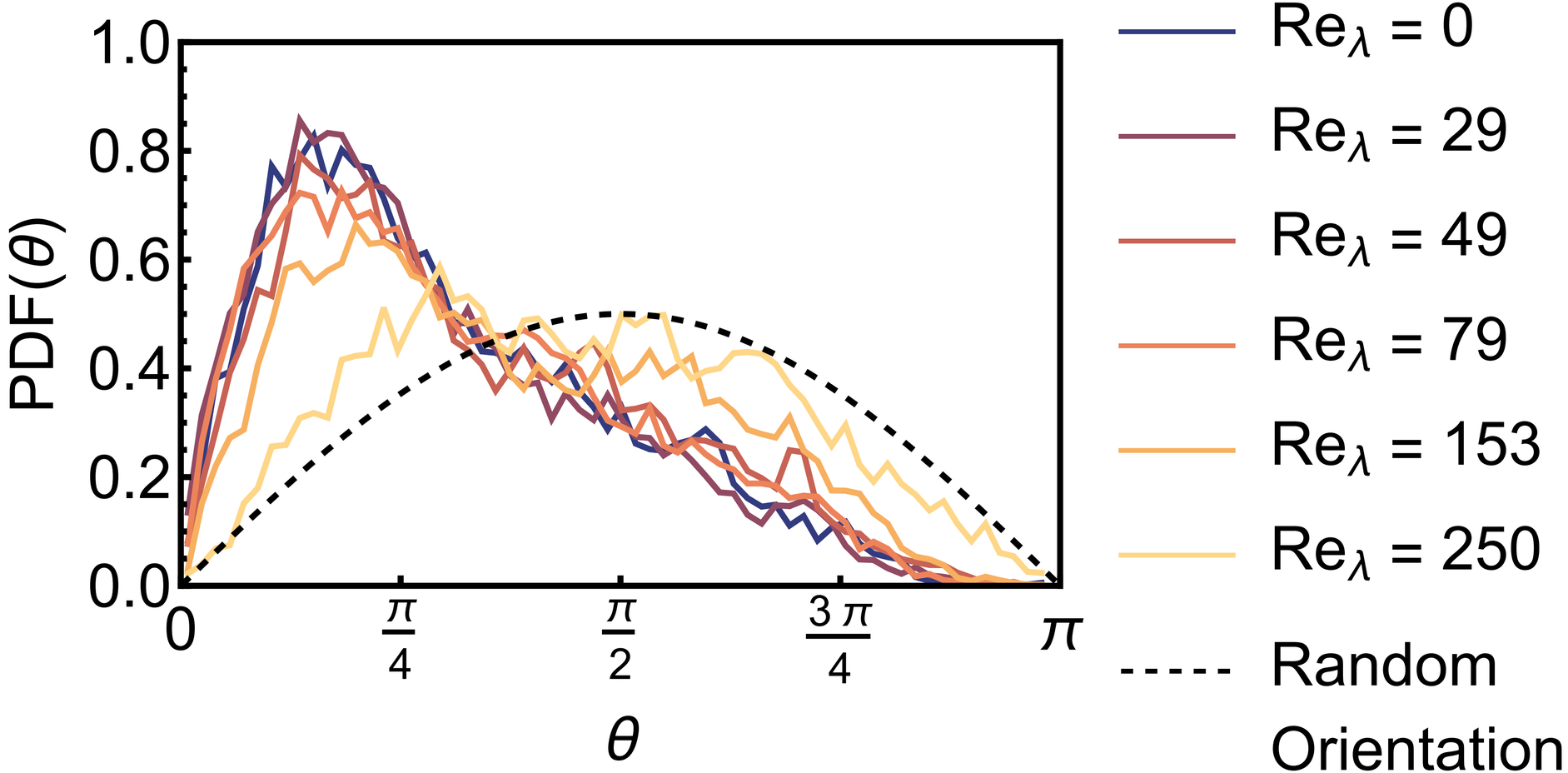


Orientation analysis

Orientation analysis

Orientation PDF





$Re_\lambda = 0$

$Re_\lambda = 29$

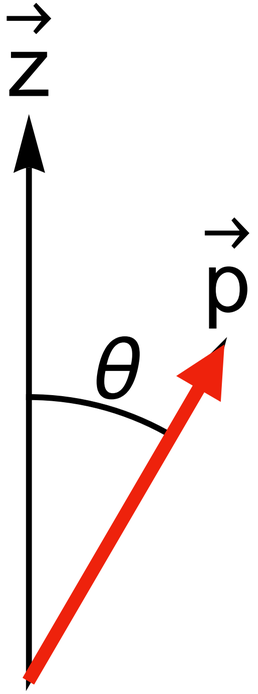
$Re_\lambda = 49$

$Re_\lambda = 79$

$Re_\lambda = 153$

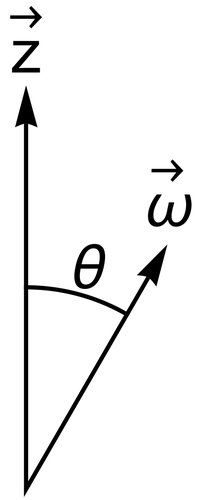
$Re_\lambda = 250$

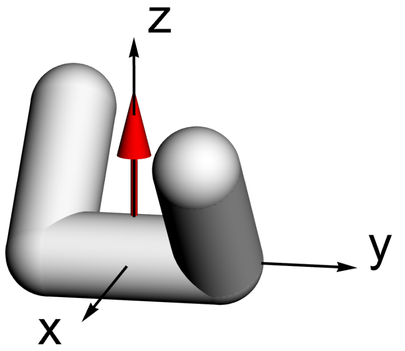
Random Orientation



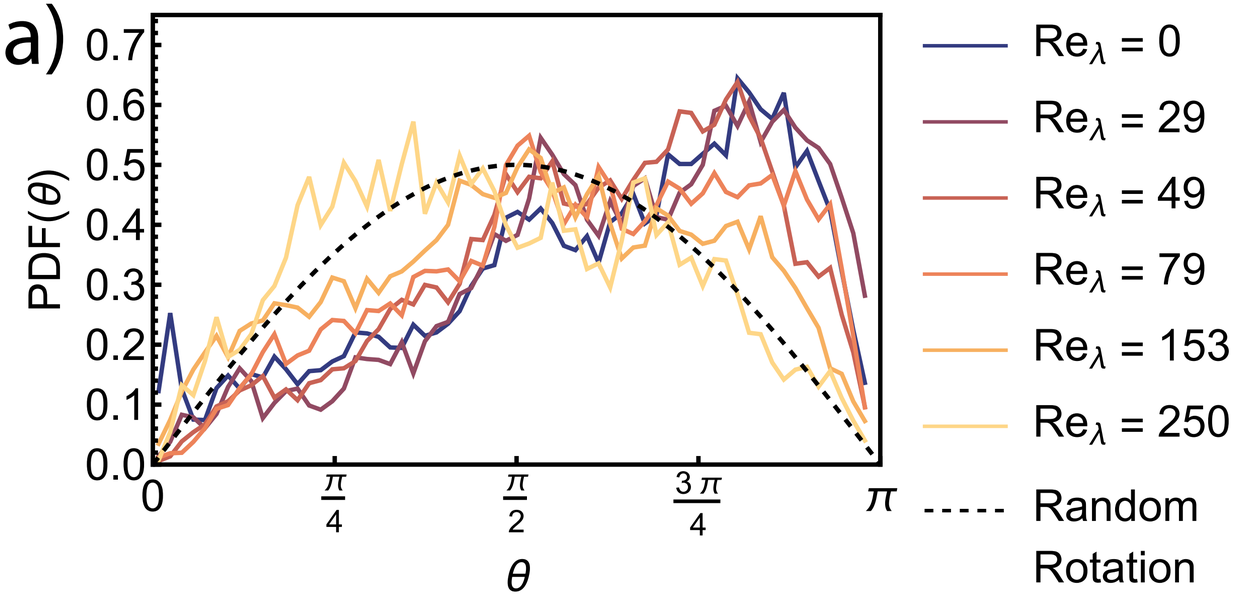
Rotation analysis

Angular velocity PDF



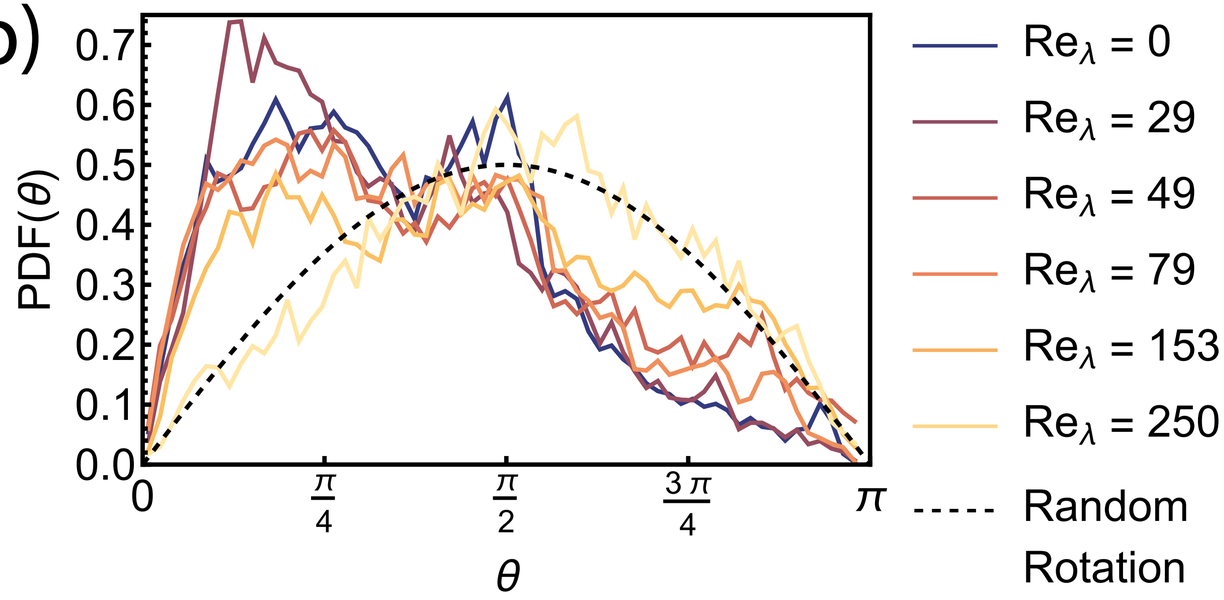


a)



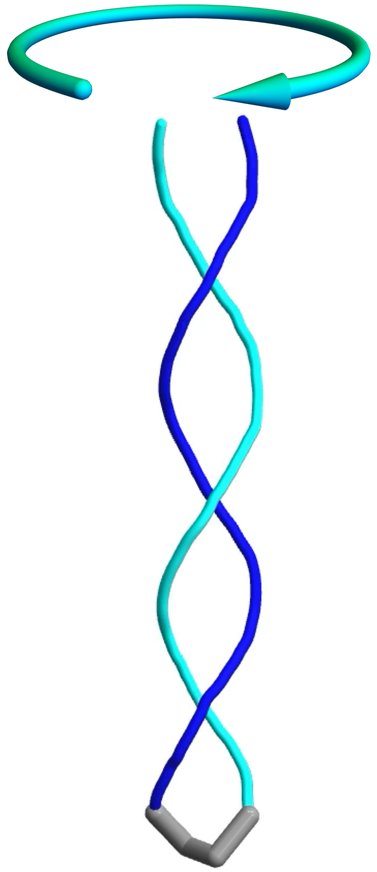
Left-handed particles

b)

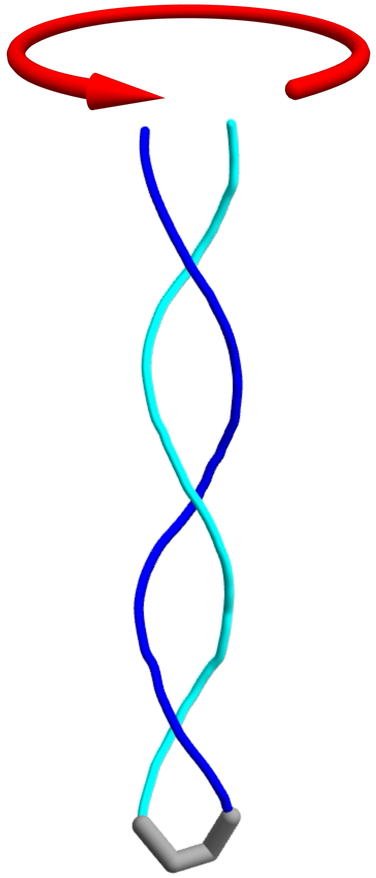


Right-handed particles

Preferred rotation



Left-handed



Right-handed

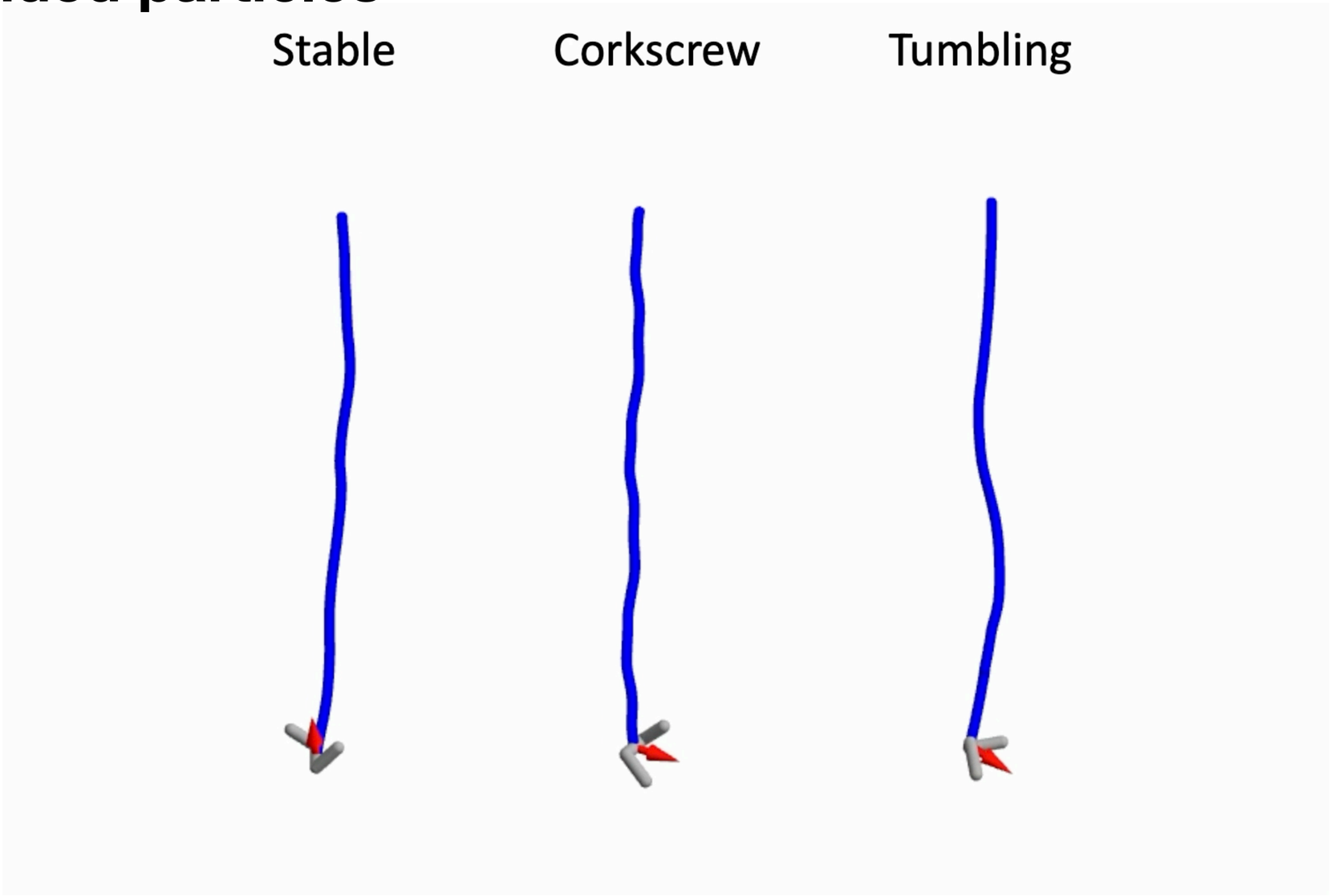
Multiple settling modes

Stable

Tumbling

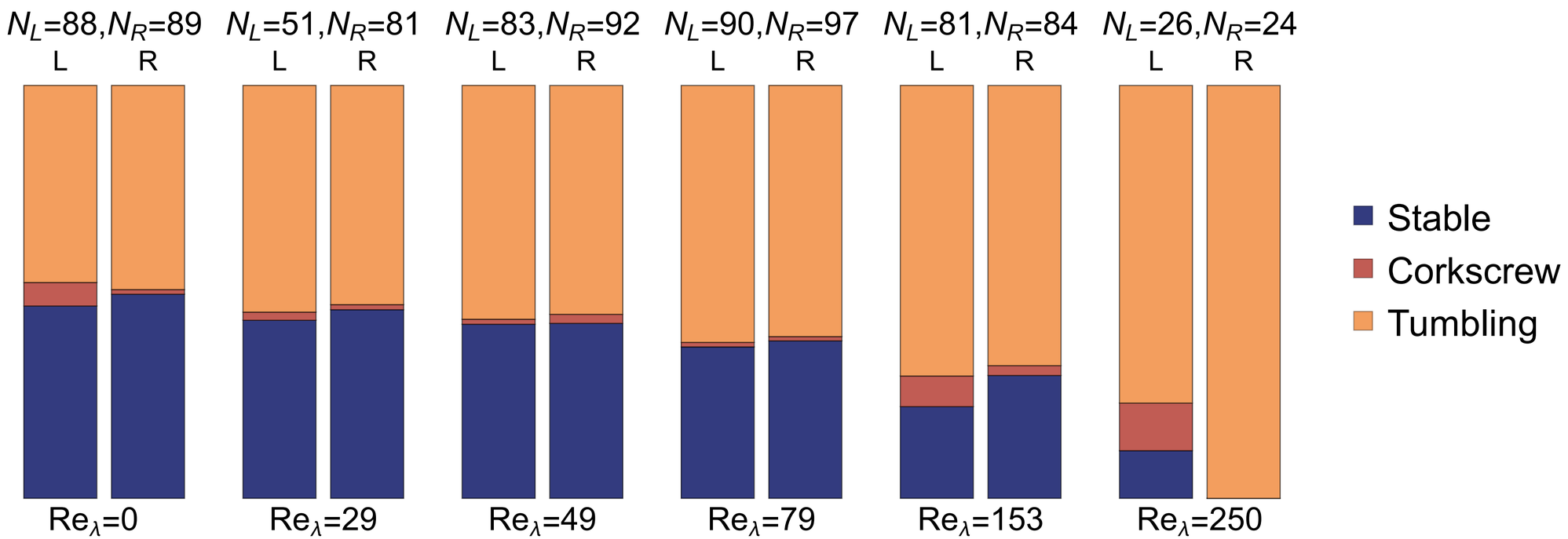
Multiple settling modes

Left-handed particles



Multiple settling modes

Occurrence of modes



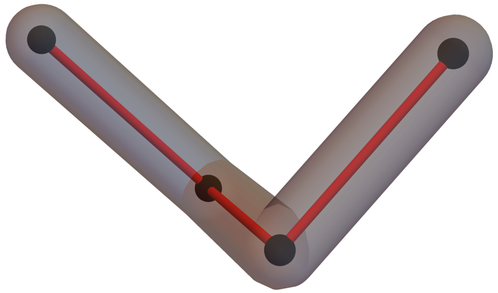
Theoretical model

Simplified particle in Stokes flow

$$v_i = G_{ij} \cdot f_j, \quad i \neq j$$

Velocity — Oseen Mobility Tensor — Force

Krapf et al. Phys. Rev. E, **79** (2009)

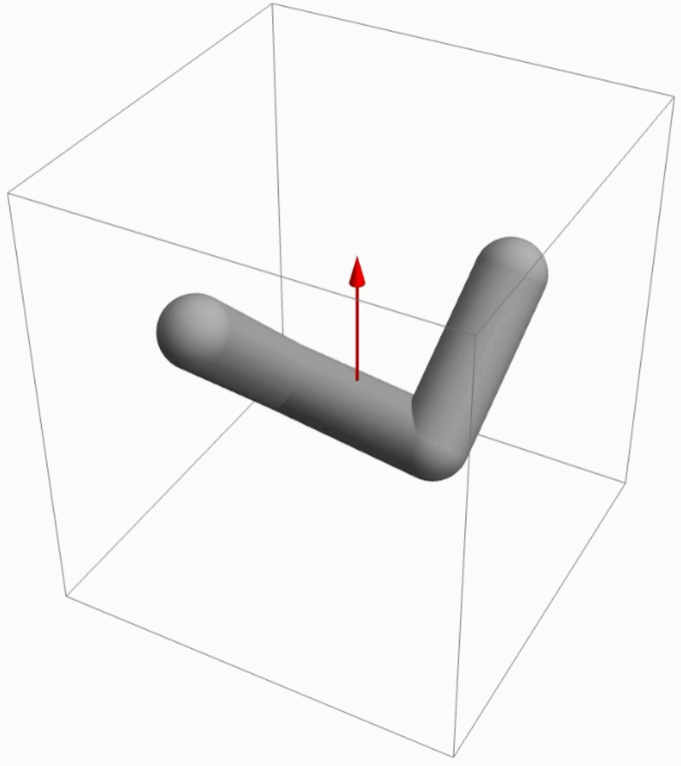


Spheres connected by rigid rods

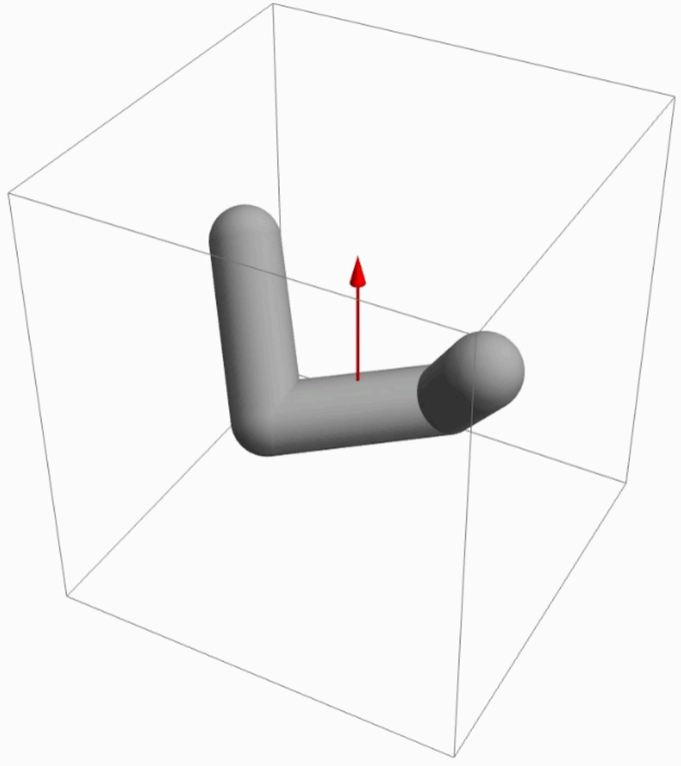
Theoretical model

No added turbulence

Left-handed

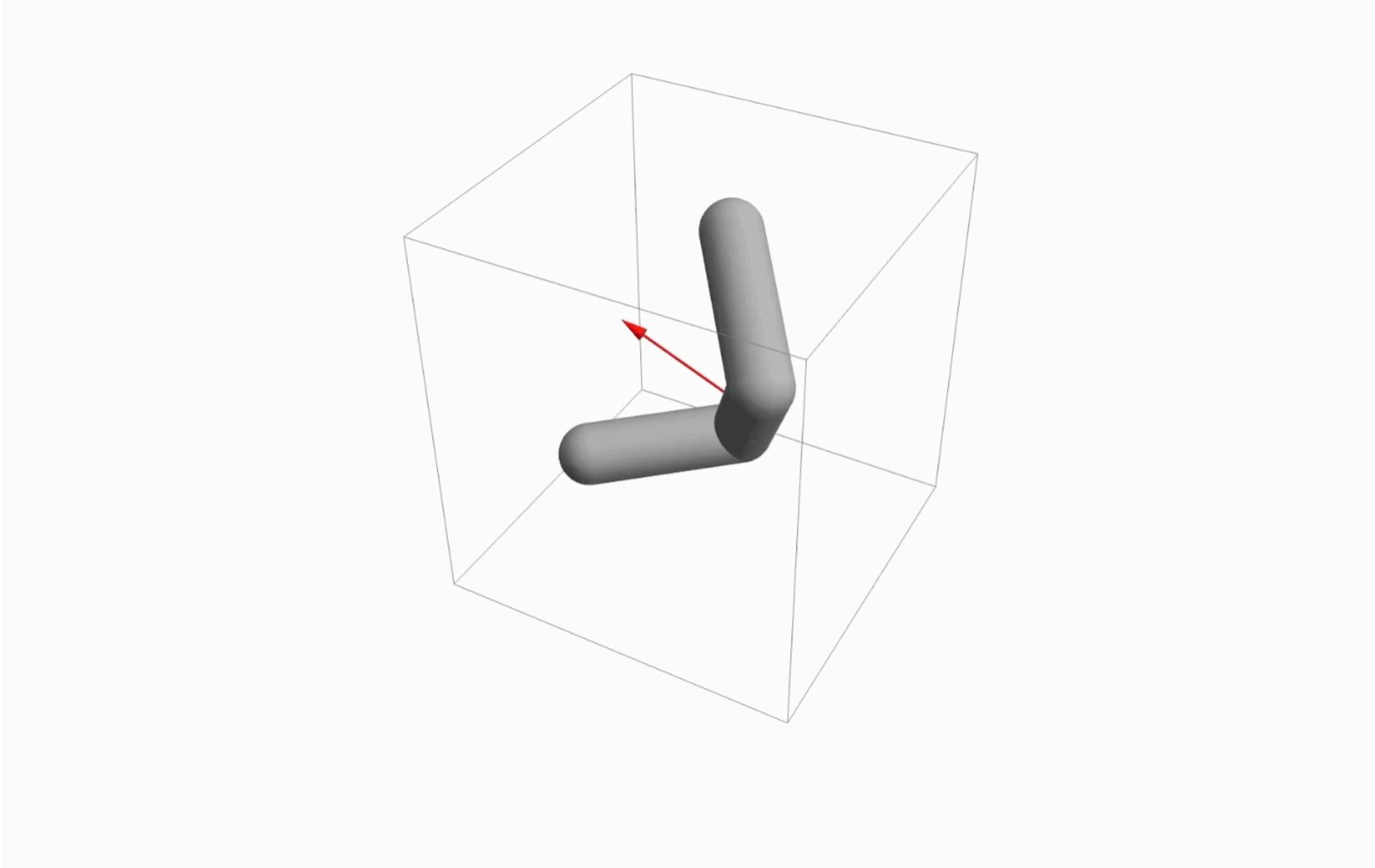


Right-handed



Theoretical model

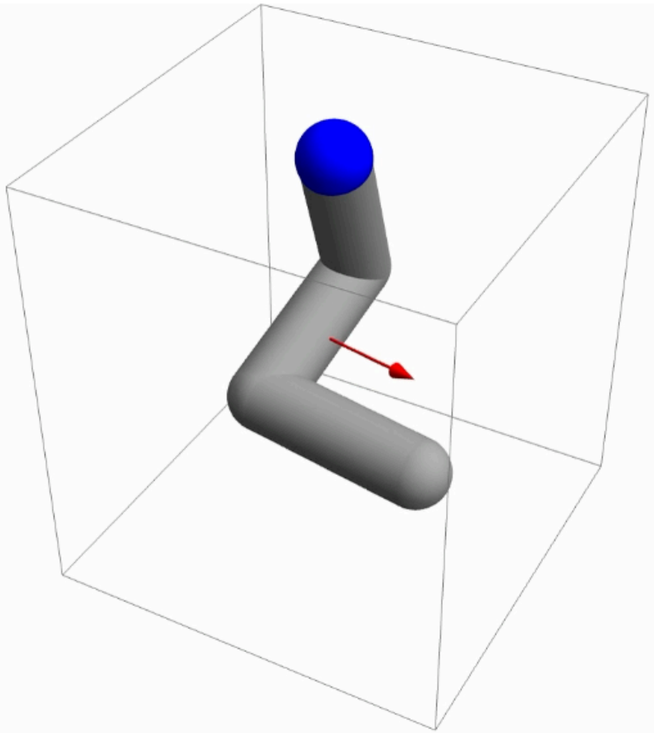
Turbulent forcing



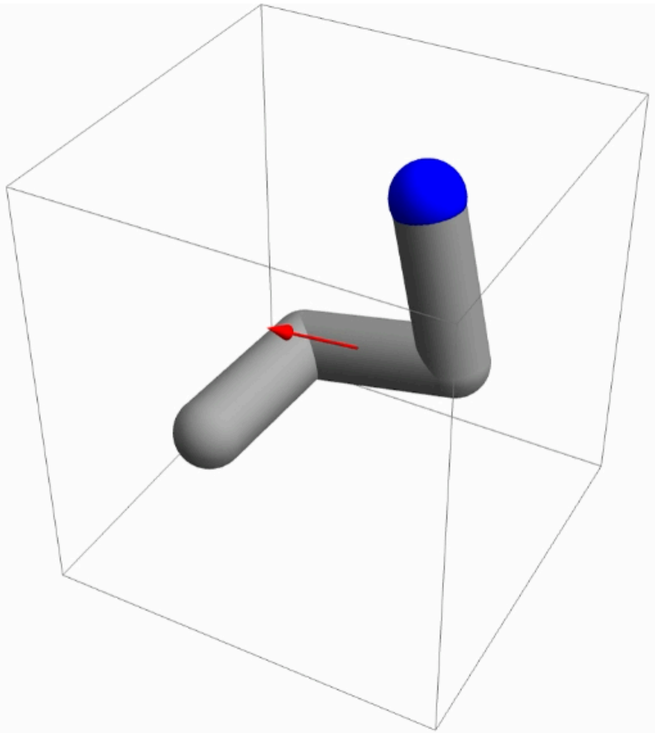
Corkscrew settling mode

Corkscrew settling mode

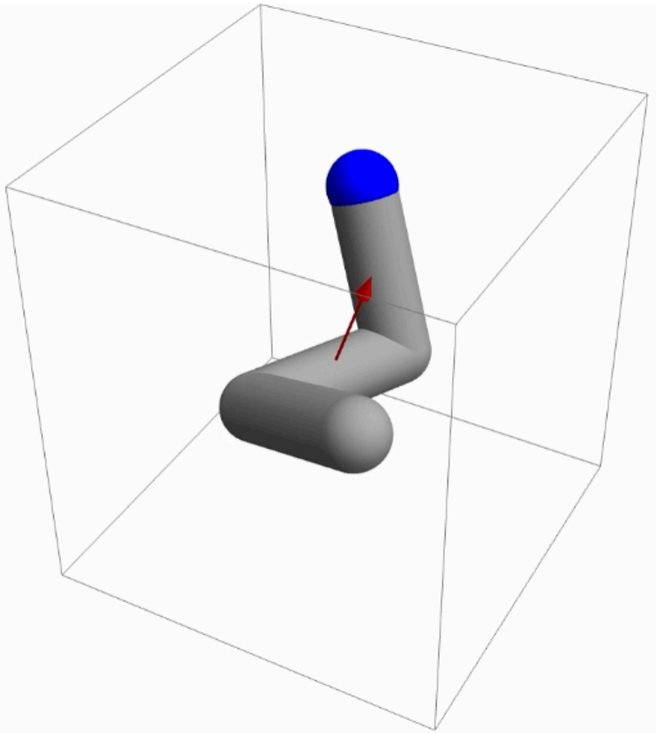
Variation of mass



$m_f = 0.51$



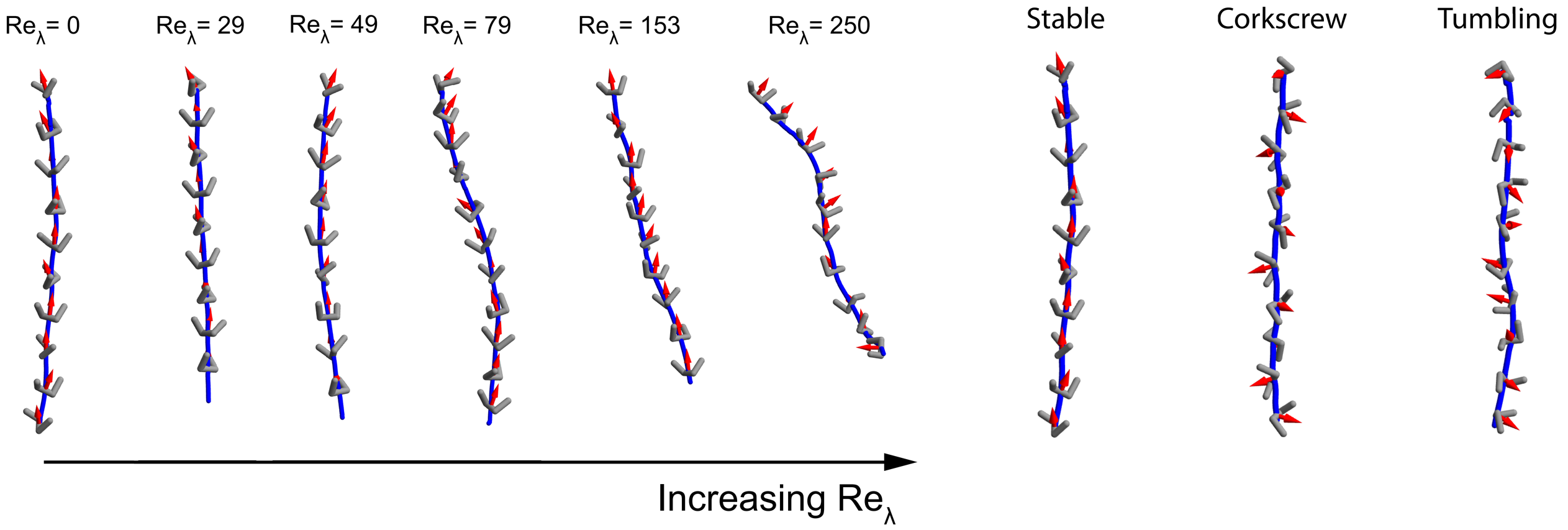
$m_f = 0.73$



$m_f = 0.91$

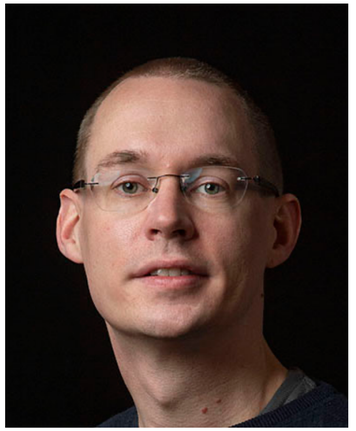
Conclusions

Settling chiral particles



Acknowledgements

Sander Huisman



Detlef Lohse

John Sader

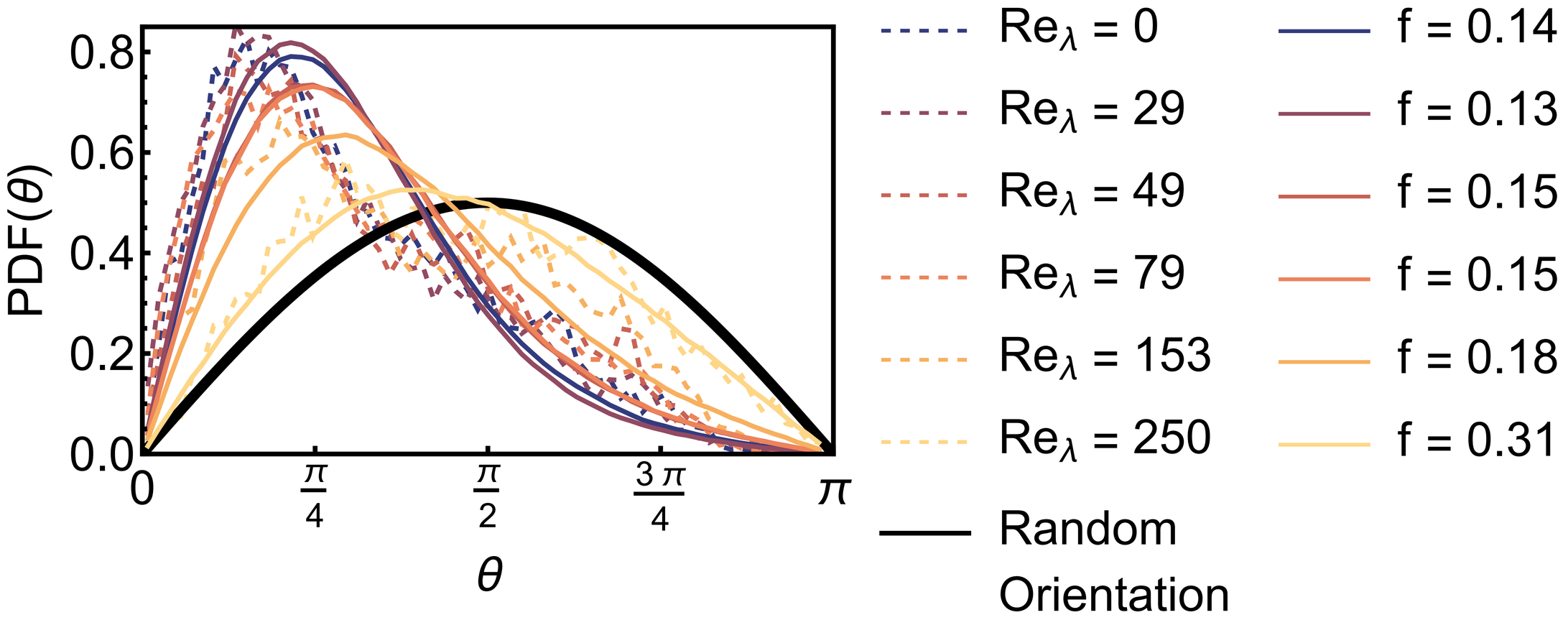
Gert-Wim Bruggert

Martin Bos

Thomas Zijlstra

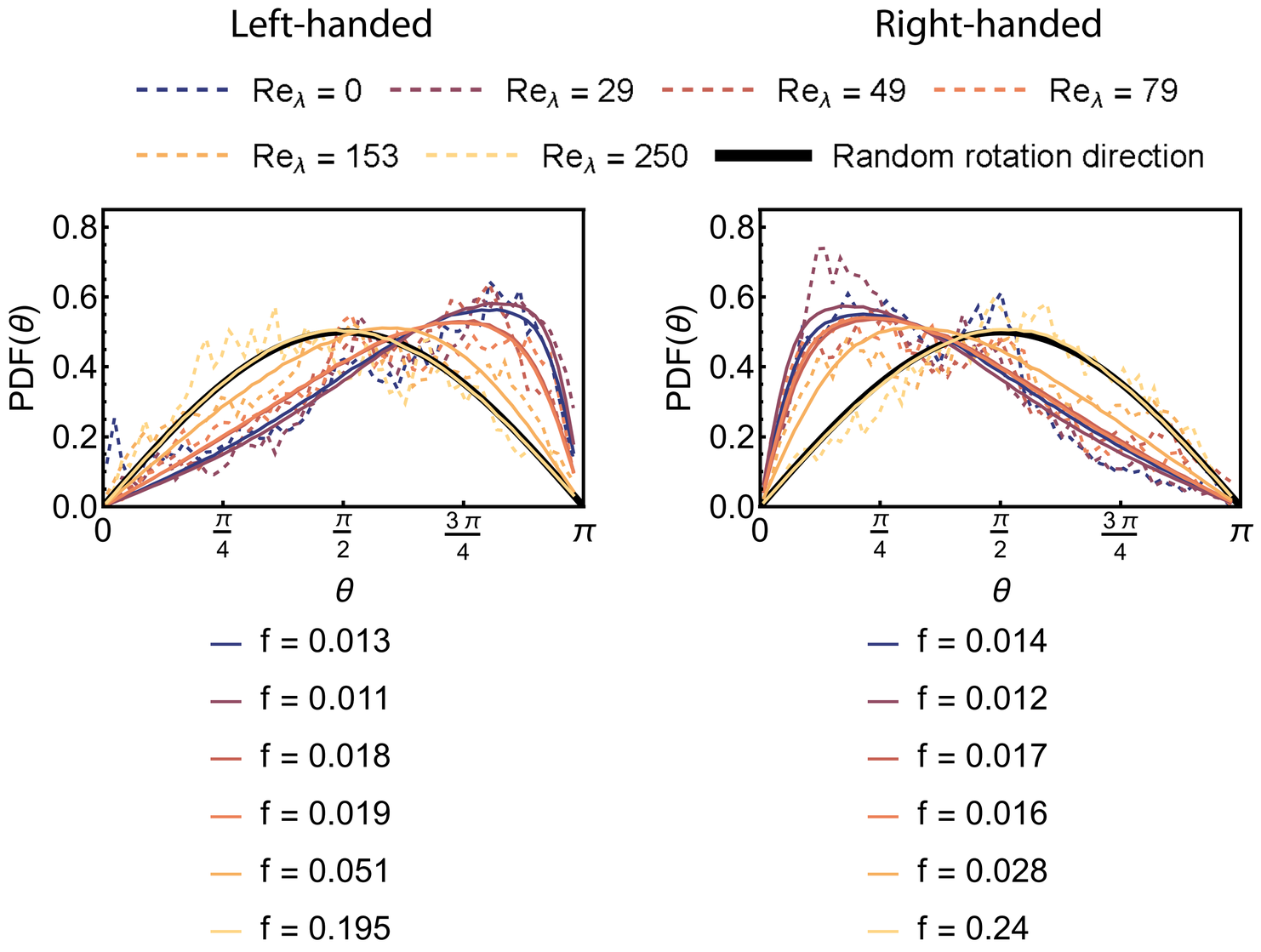
Preferential alignment

Experiment vs. Theory



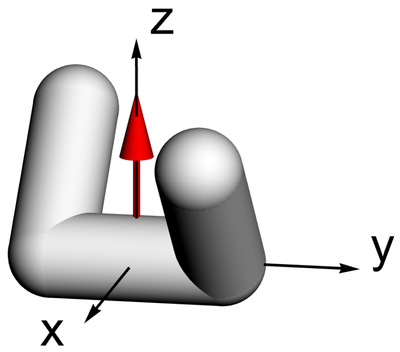
Preferential rotation

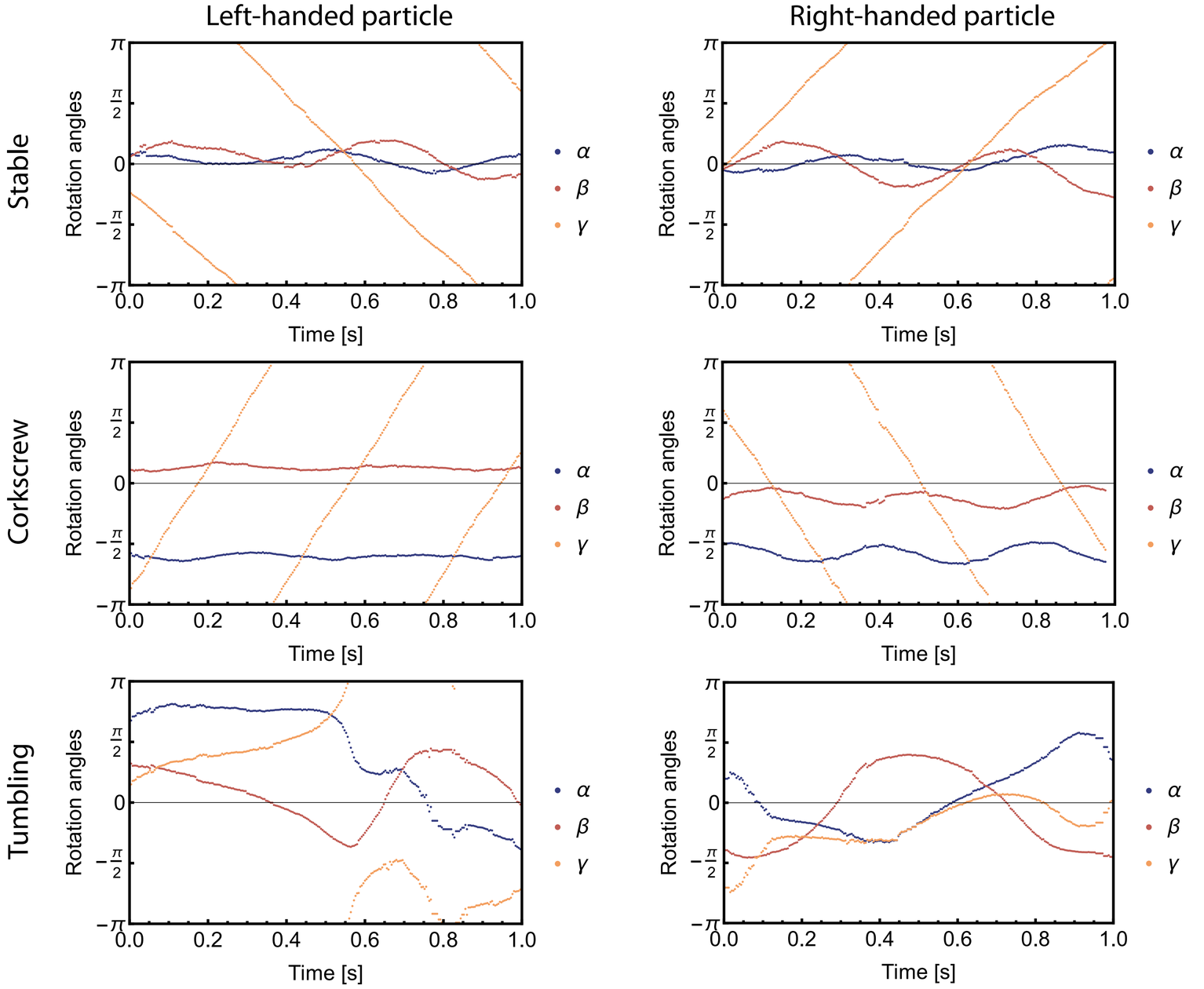
Experiment vs. Theory



Rotation angles

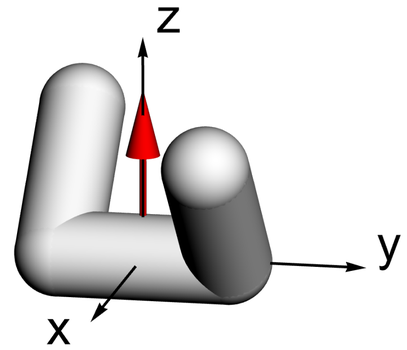
Experiments

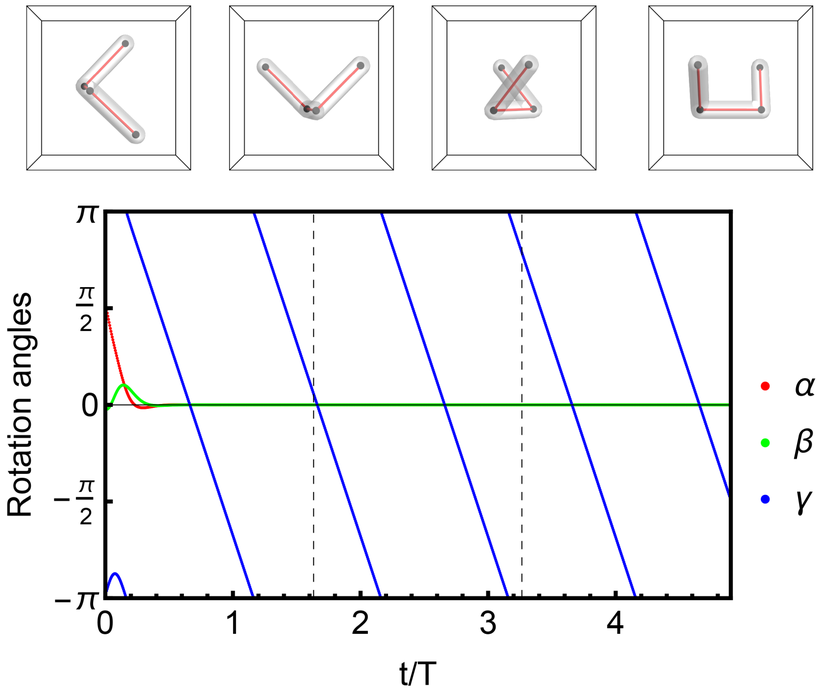


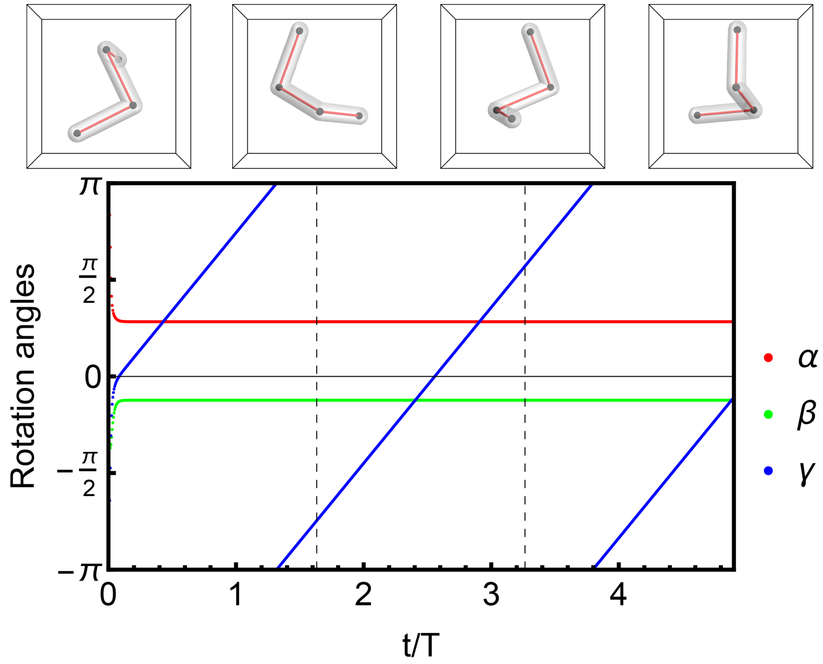


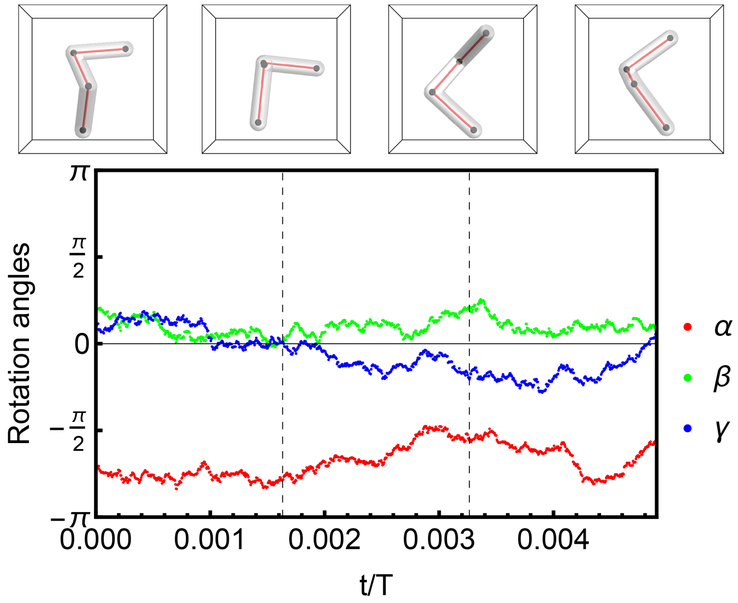
Rotation angles

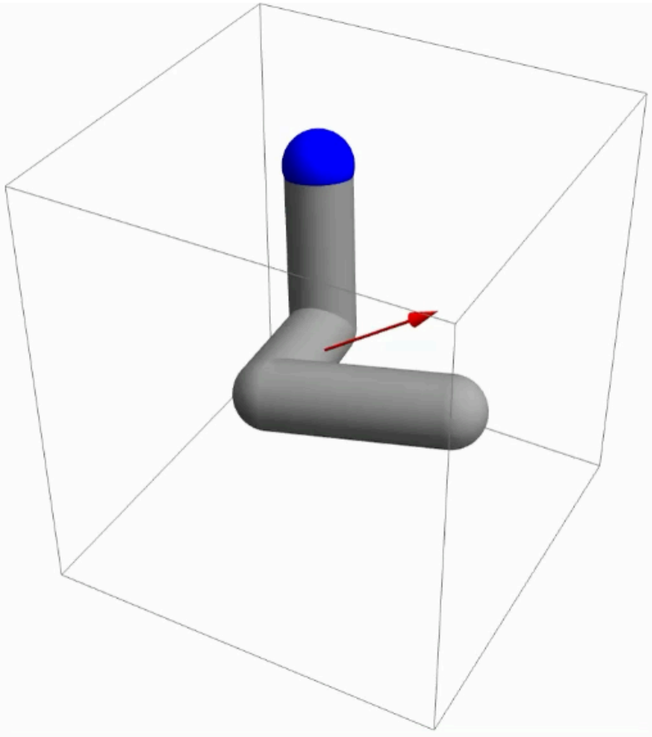
Theory



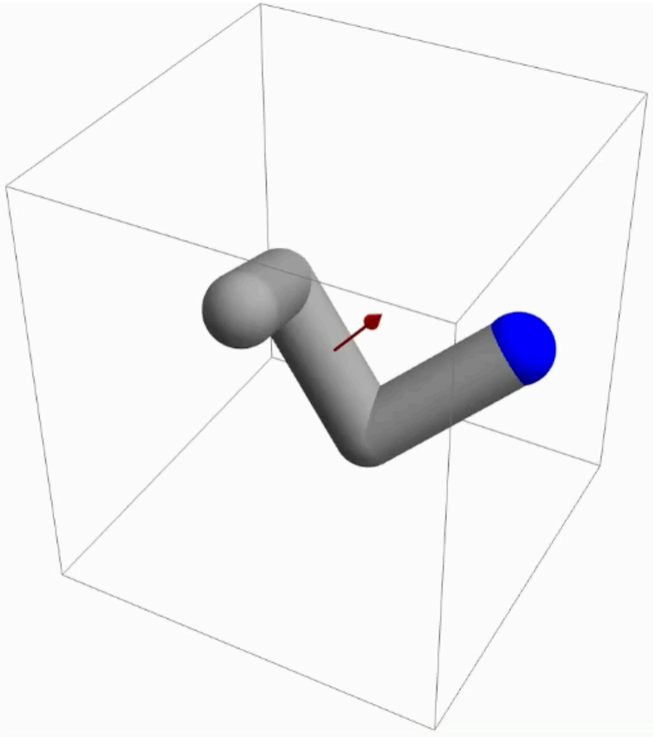




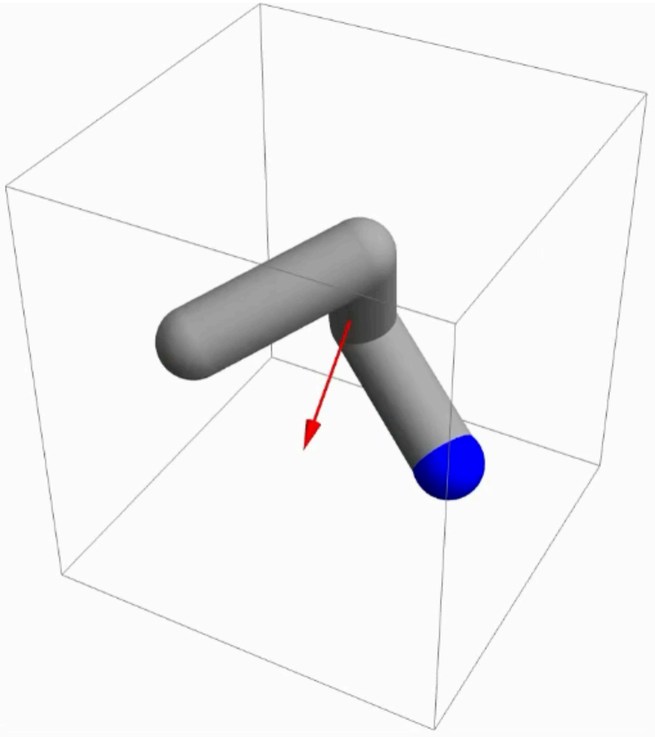




$m_f = 0.51$



$m_f = 0.73$



$m_f = 0.91$