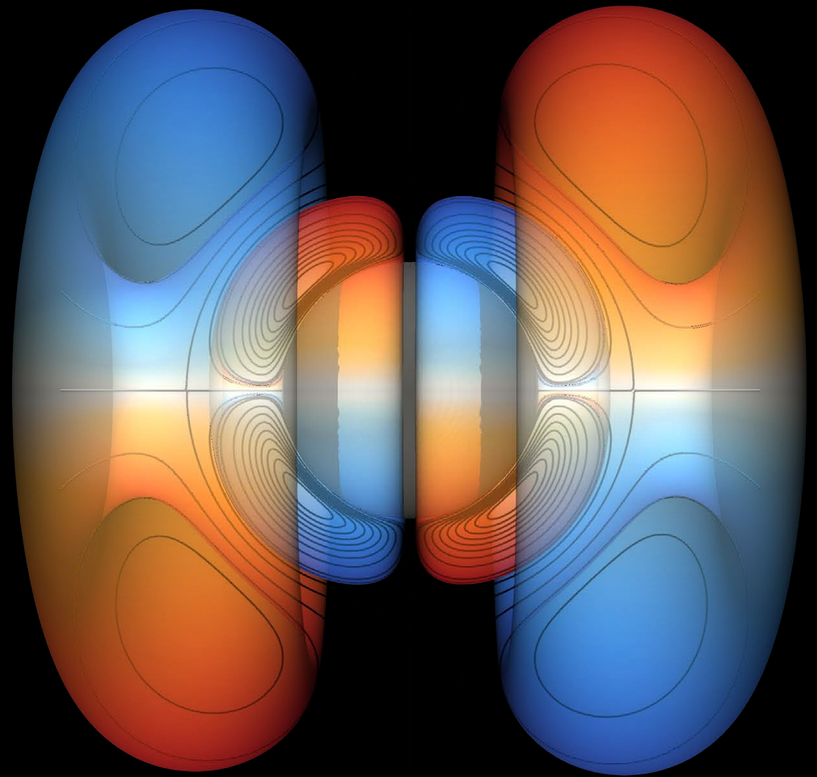
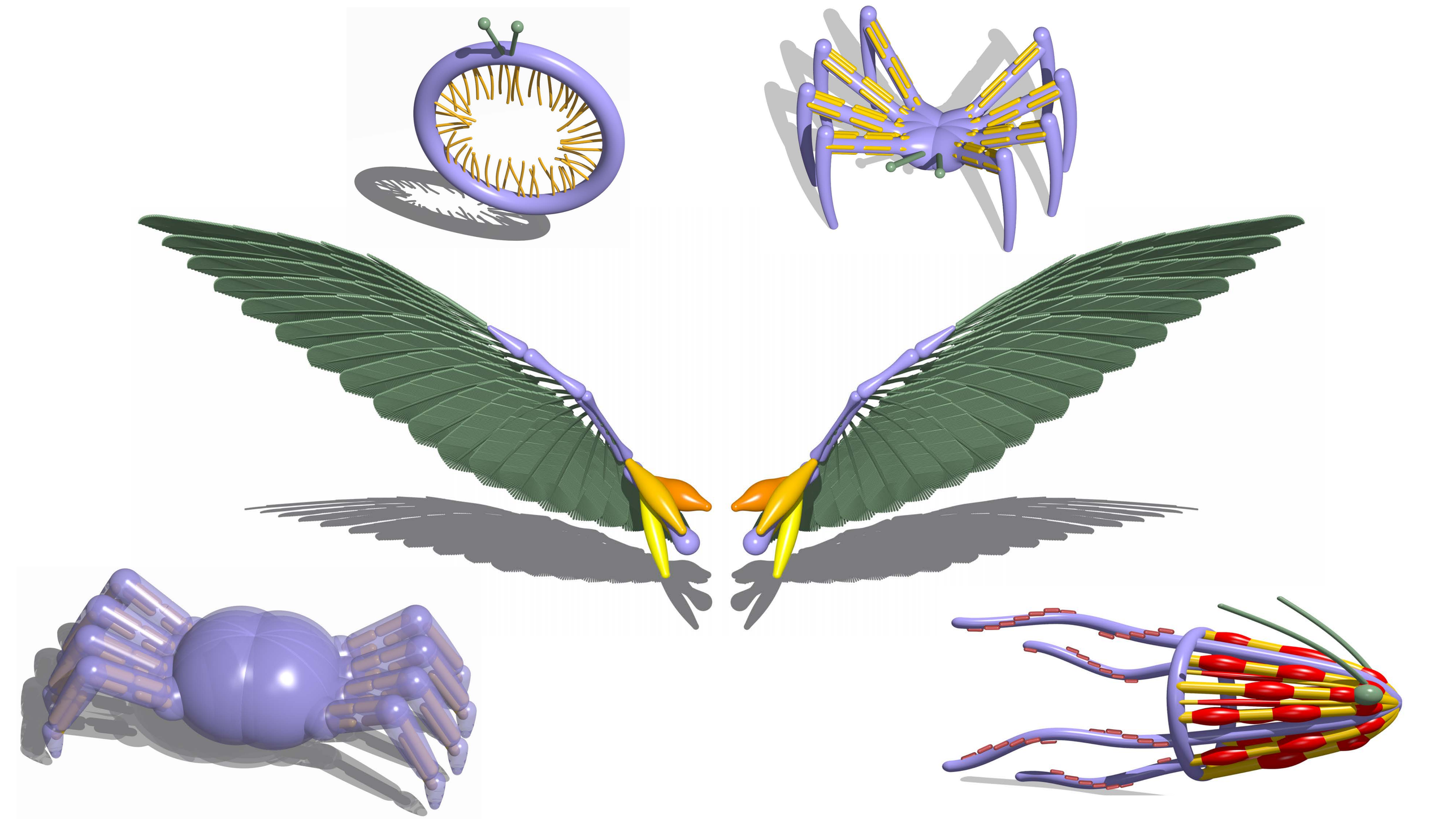
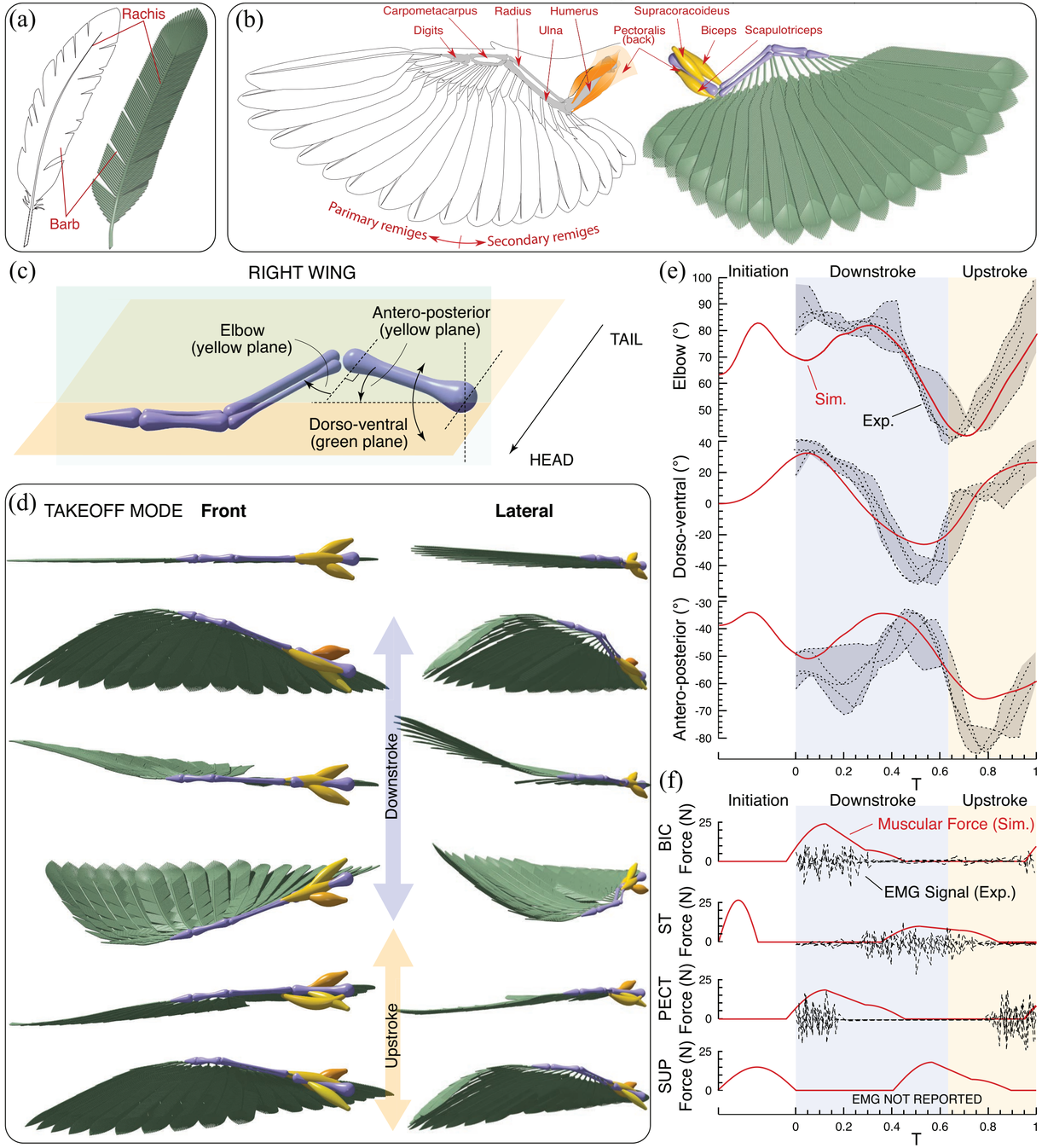
Harnessing viscous streaming in complex active systems



Mattia Gazzola
University of Illinois at Urbana-Champaign

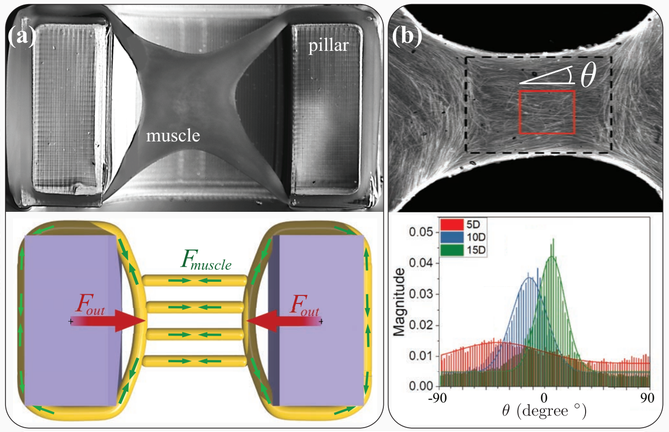


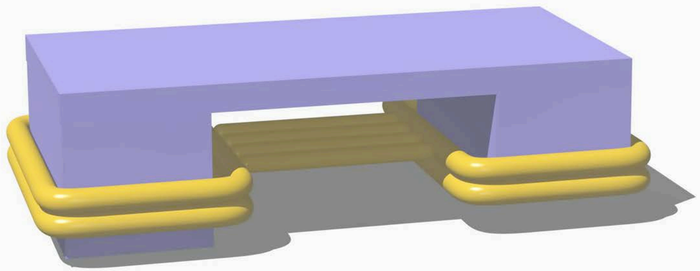


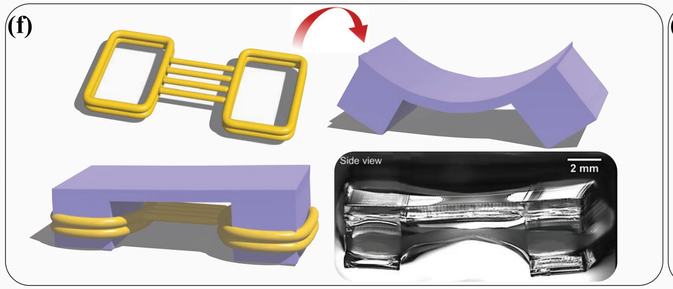
Zhang, Chan, Parthasarathy, Gazzola, **Under revision Nature Communications**, 2019.

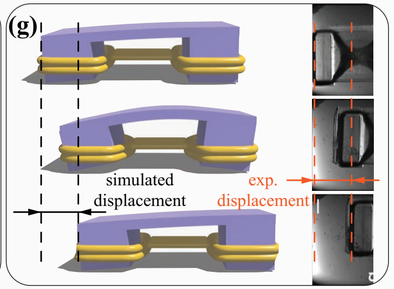
CHARACTERIZATION & MODELING

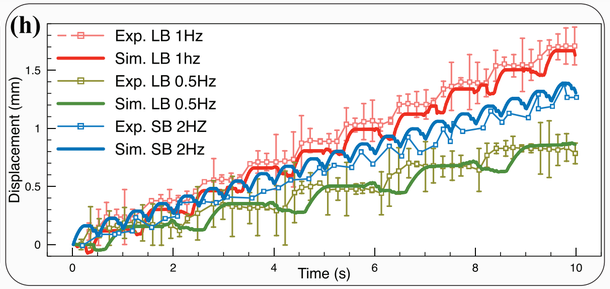
PREDICTIVE DESIGN

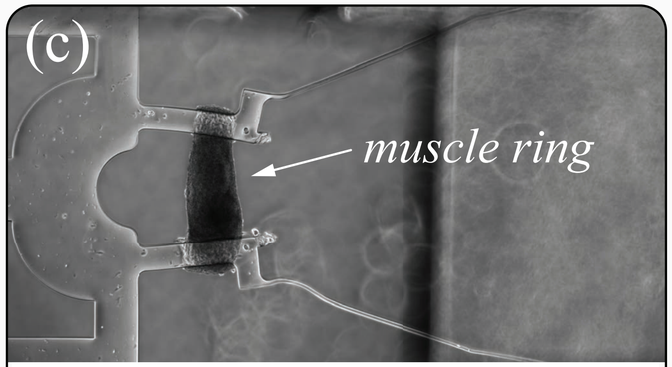


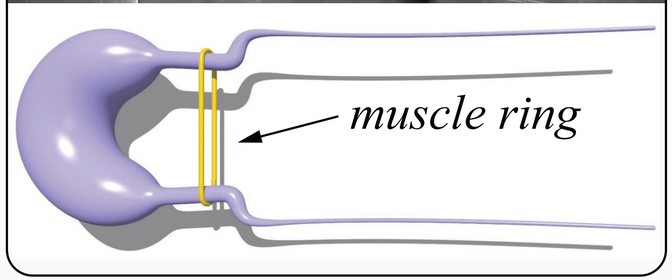


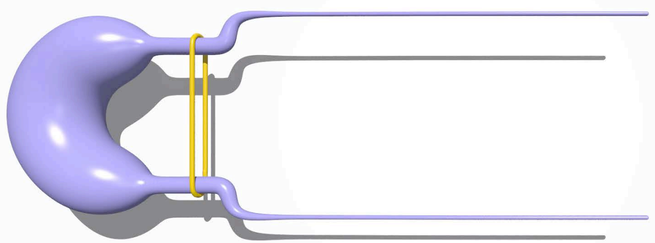




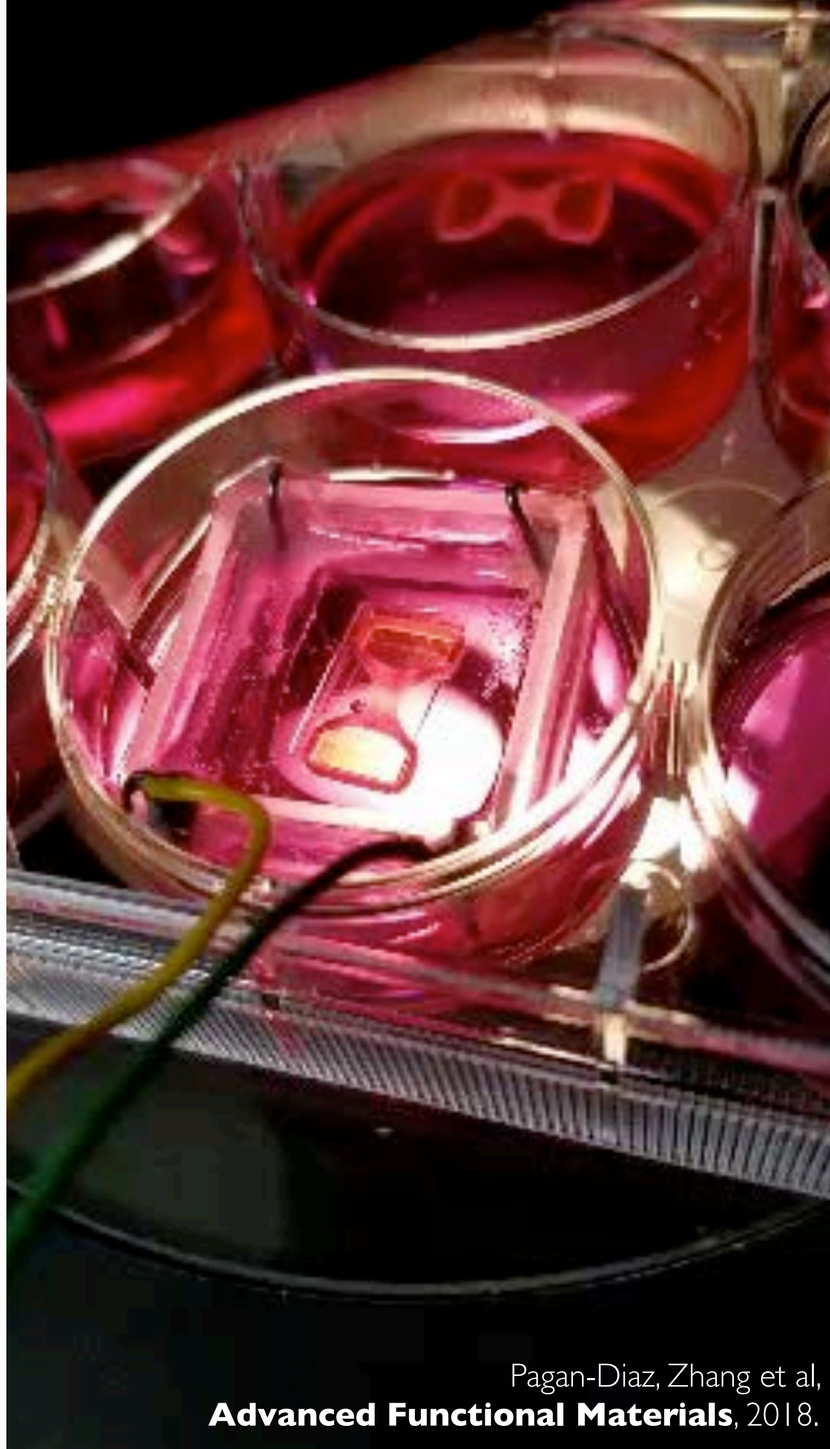








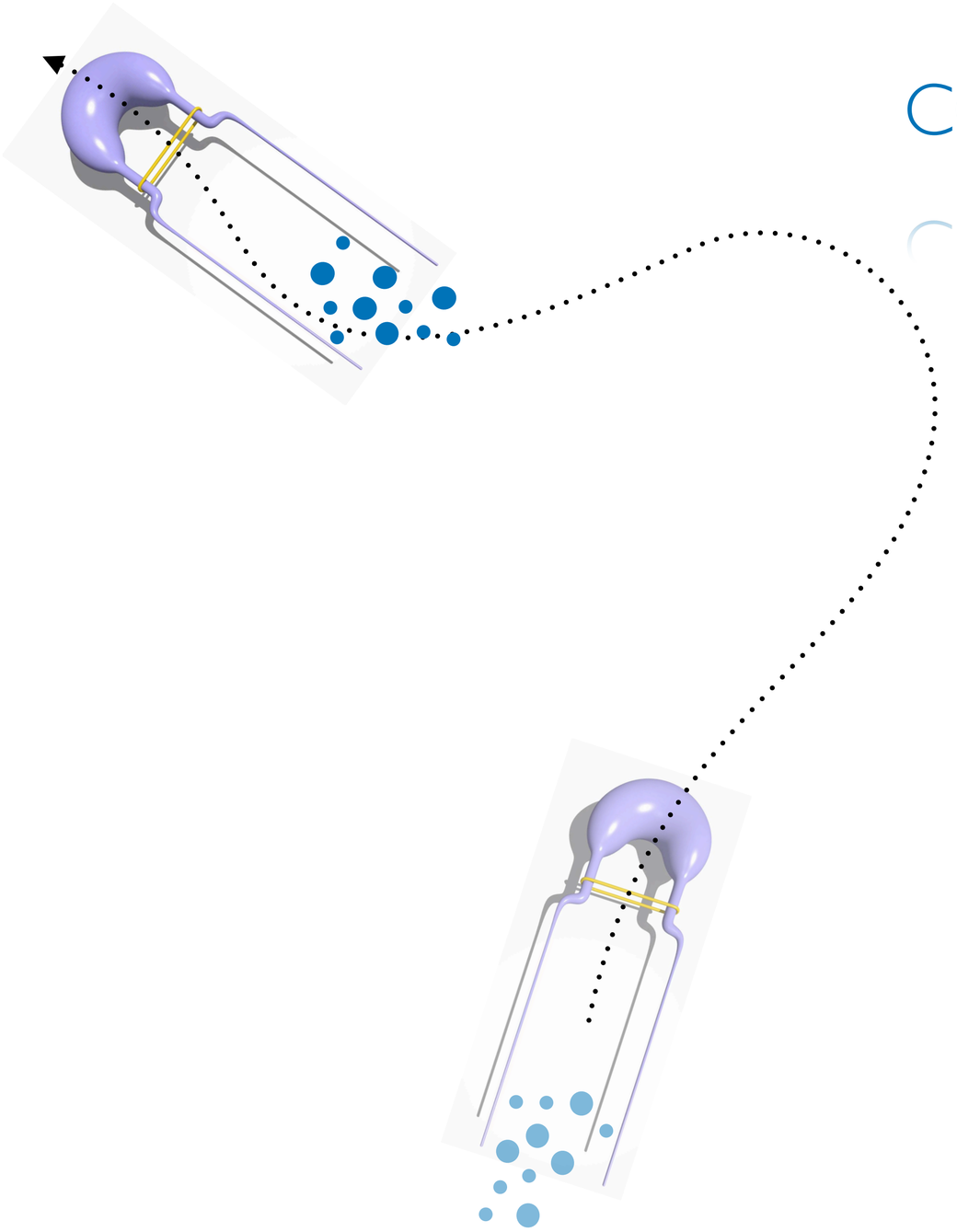
Aydin, Zhang et al.
Under revision PNAS, 2019.



Pagan-Diaz, Zhang et al,
Advanced Functional Materials, 2018.

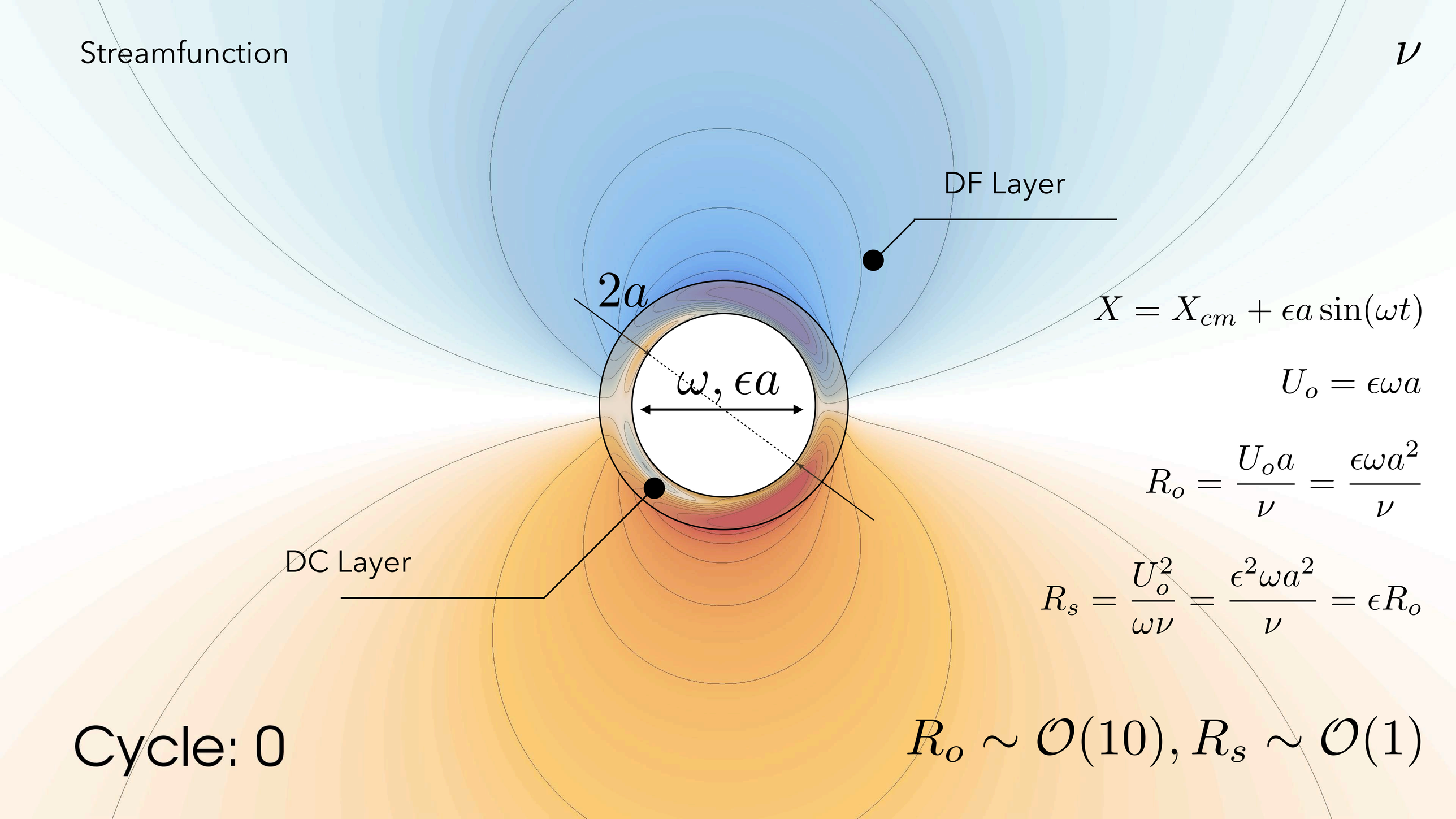
FLOW CONTROL

Van Dyke ‘82



Streamfunction

ν



$$X = X_{cm} + \epsilon a \sin(\omega t)$$

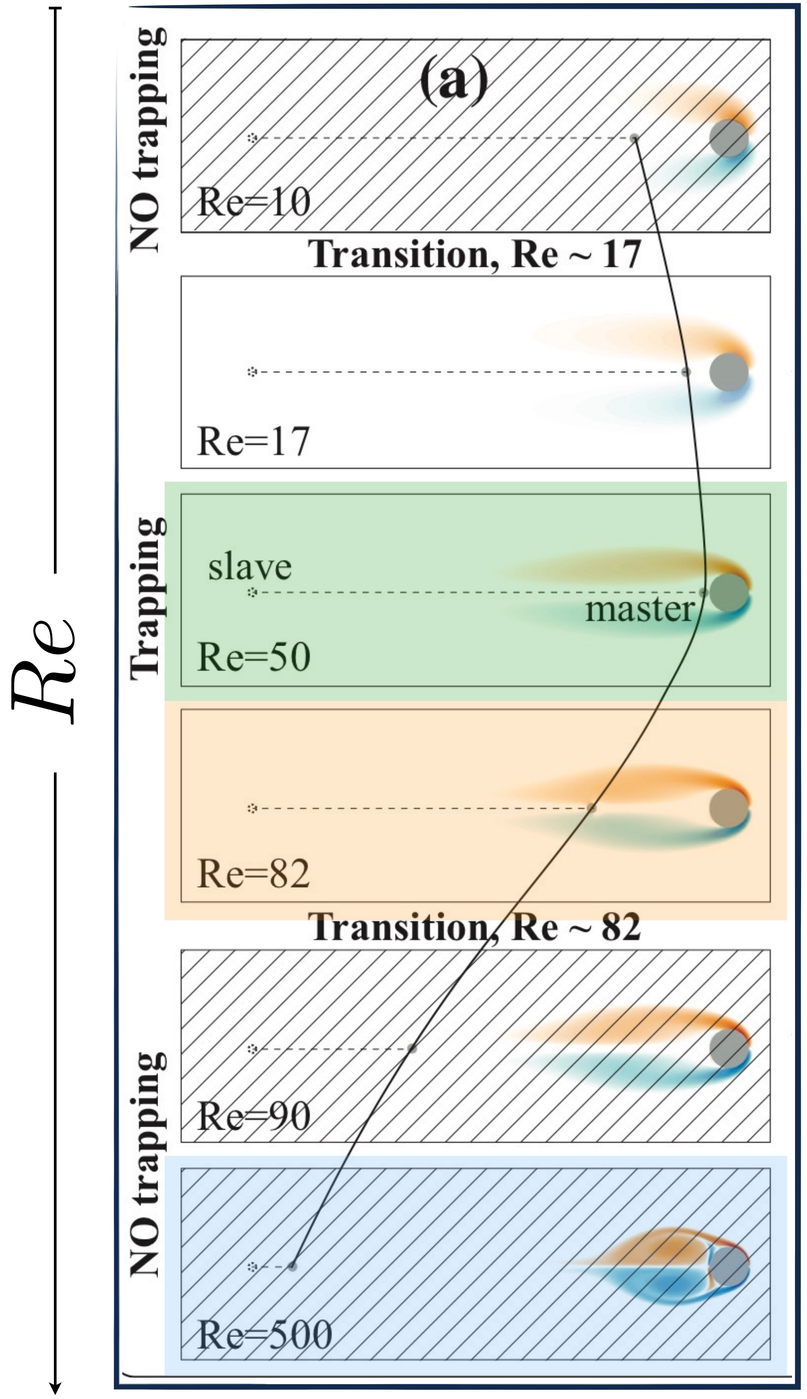
$$U_o = \epsilon \omega a$$

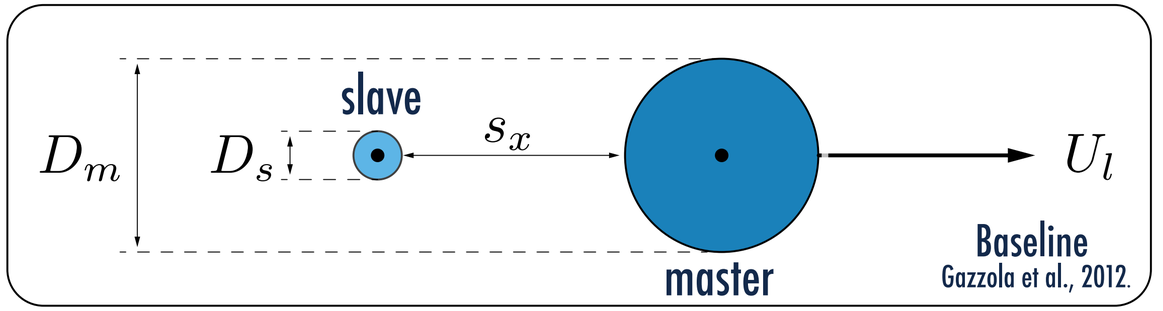
$$R_o = \frac{U_o a}{\nu} = \frac{\epsilon \omega a^2}{\nu}$$

$$R_s = \frac{U_o^2}{\omega \nu} = \frac{\epsilon^2 \omega a^2}{\nu} = \epsilon R_o$$

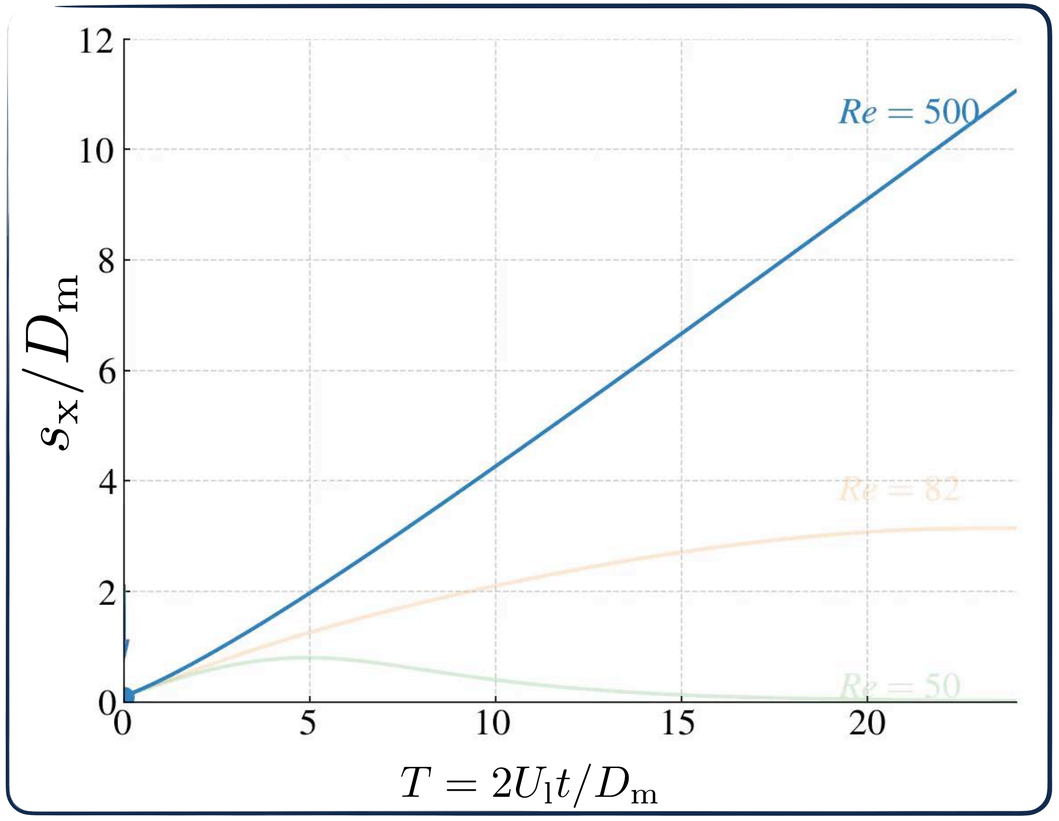
Cycle: 0

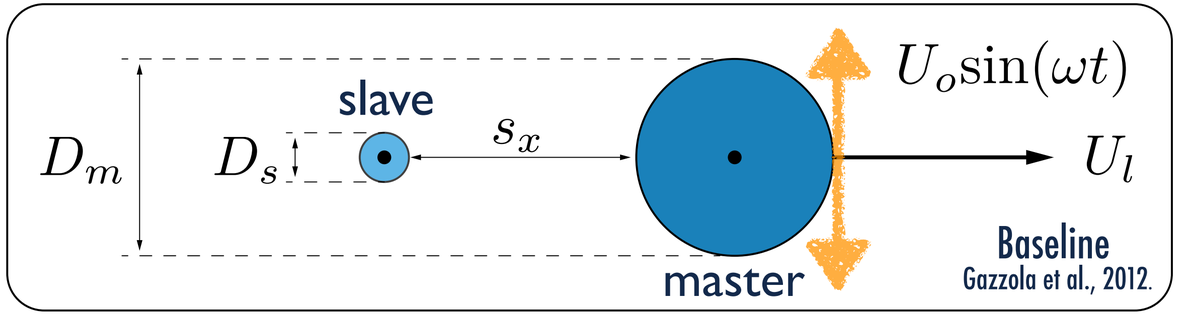
$$R_o \sim \mathcal{O}(10), R_s \sim \mathcal{O}(1)$$





$$Re = \frac{U_l D_m}{\nu}$$



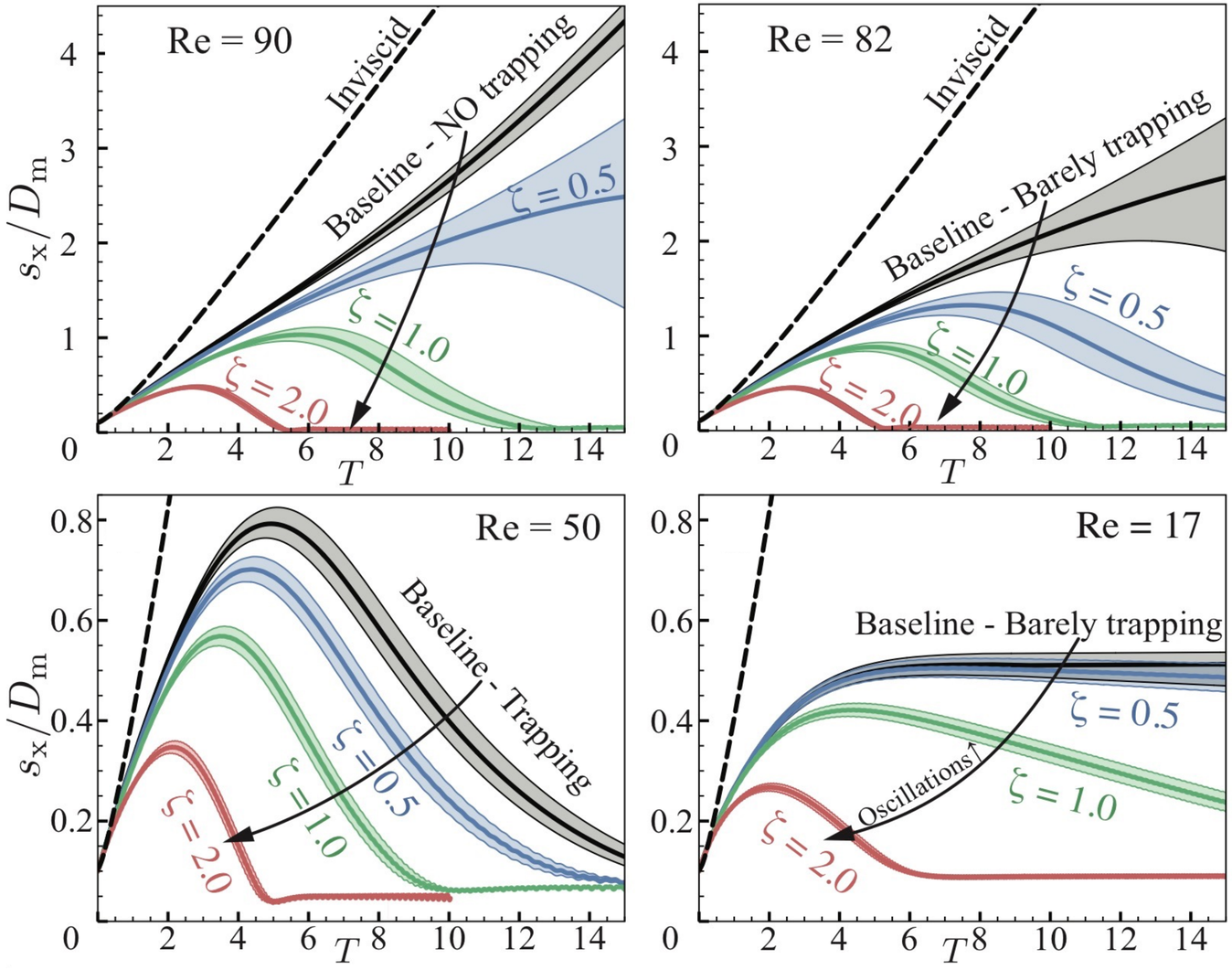


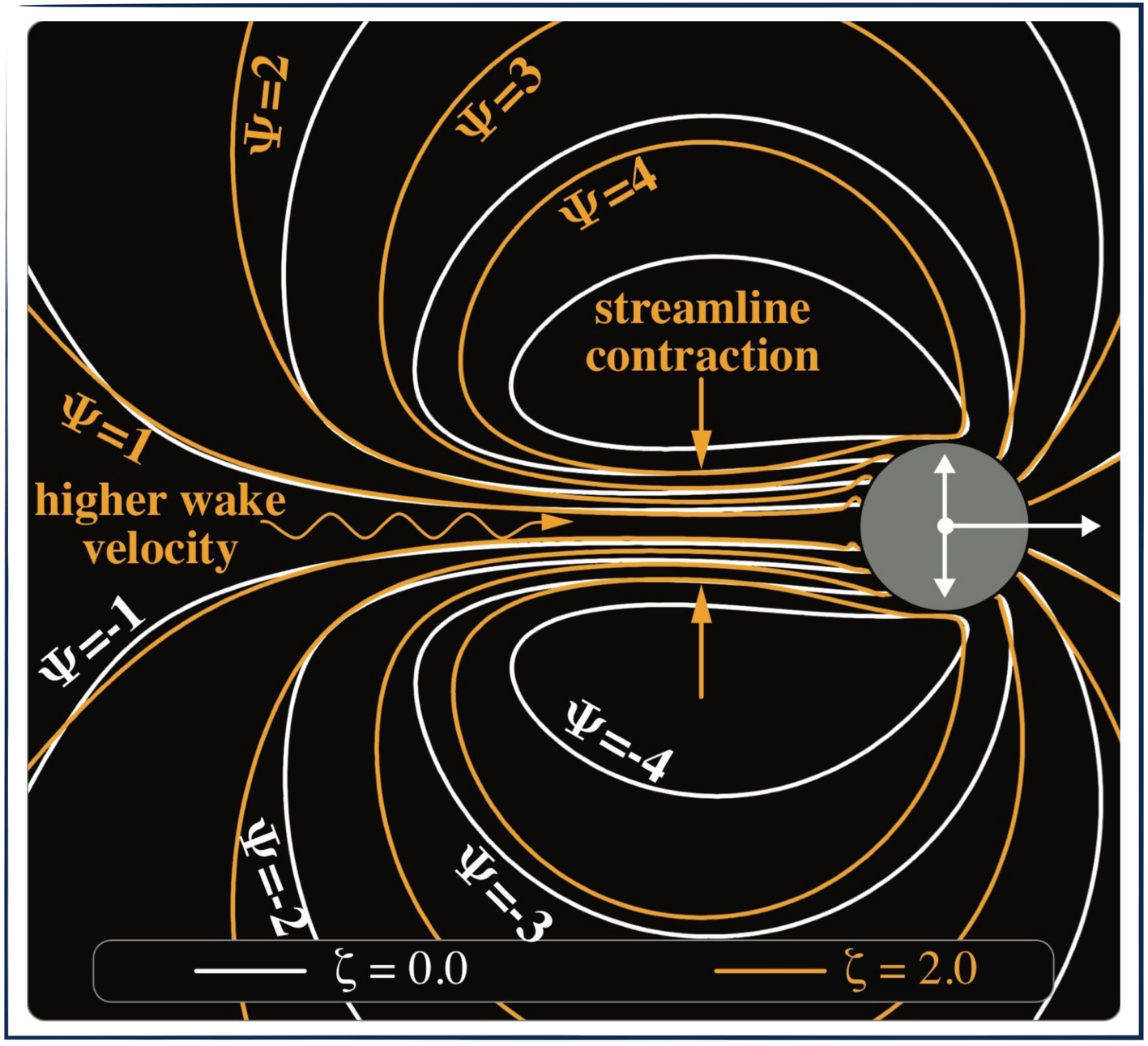
$$Re = \frac{U_l D_m}{\nu} \qquad R_o = \frac{U_o D_m}{2\nu}$$

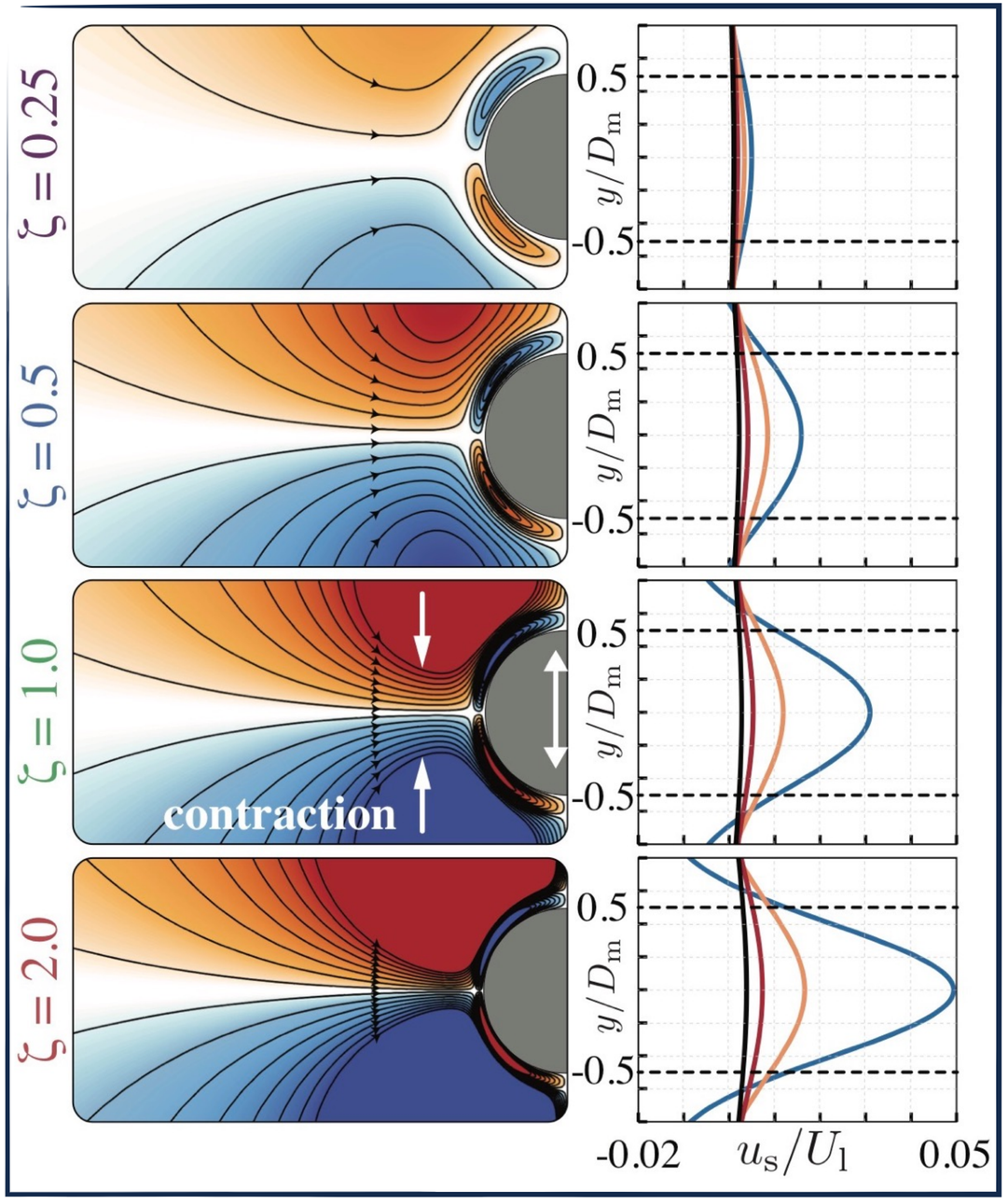
$$\zeta = \frac{R_o}{Re}$$

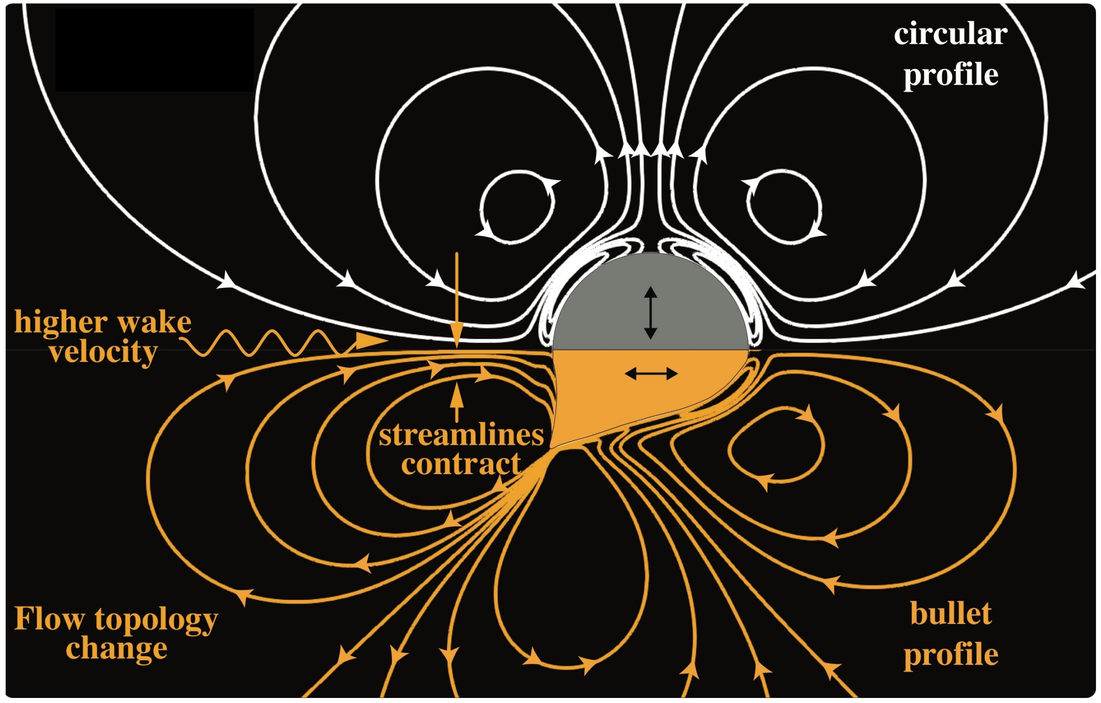
Scaled Strouhal number

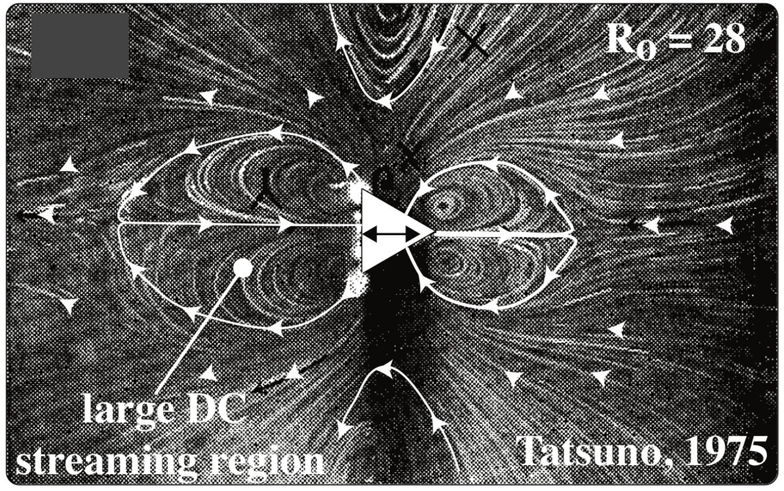
Oscillatory versus **translation** timescales

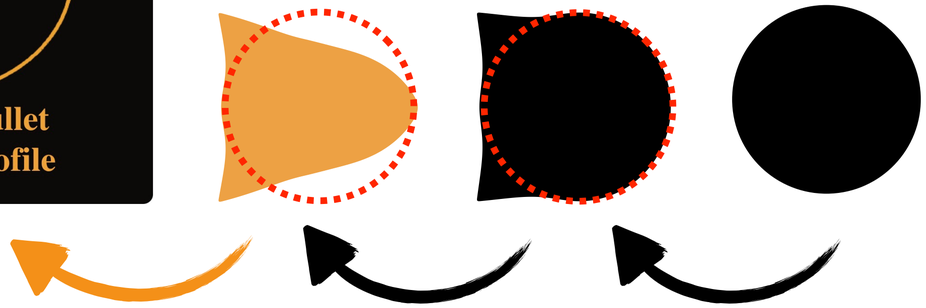


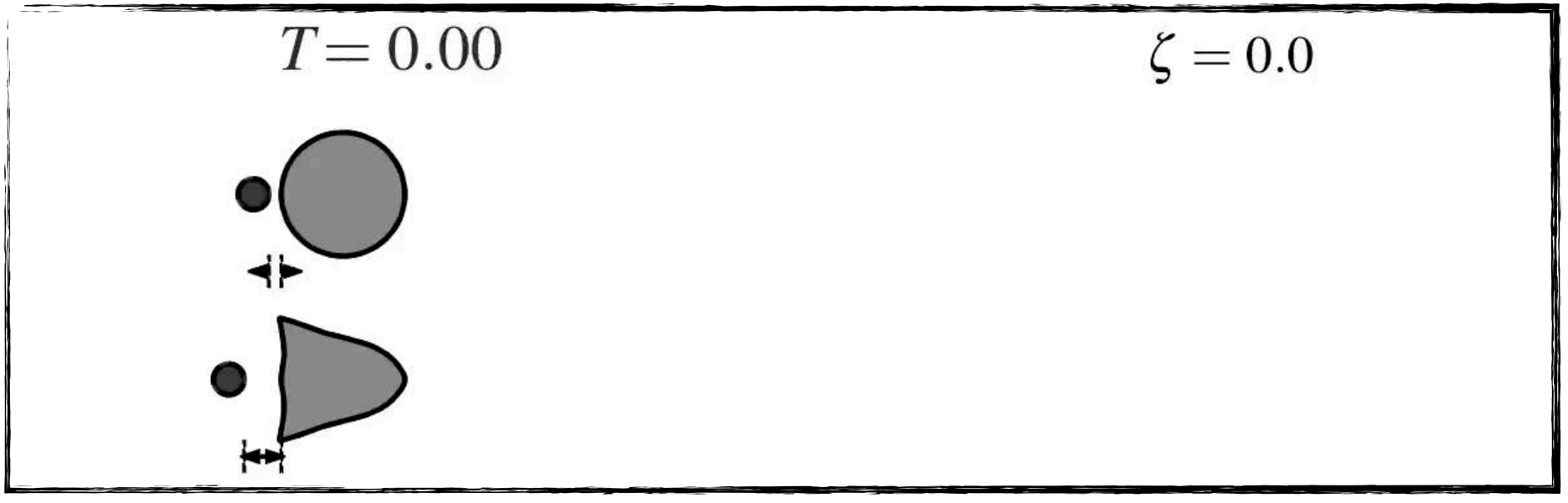

Ψ=2
Ψ=3
Ψ=4
streamline
contraction
Ψ=1
higher wake
velocity
Ψ=-1
Ψ=-4
Ψ=-2
Ψ=-3
ζ = 0.0
ζ = 2.0

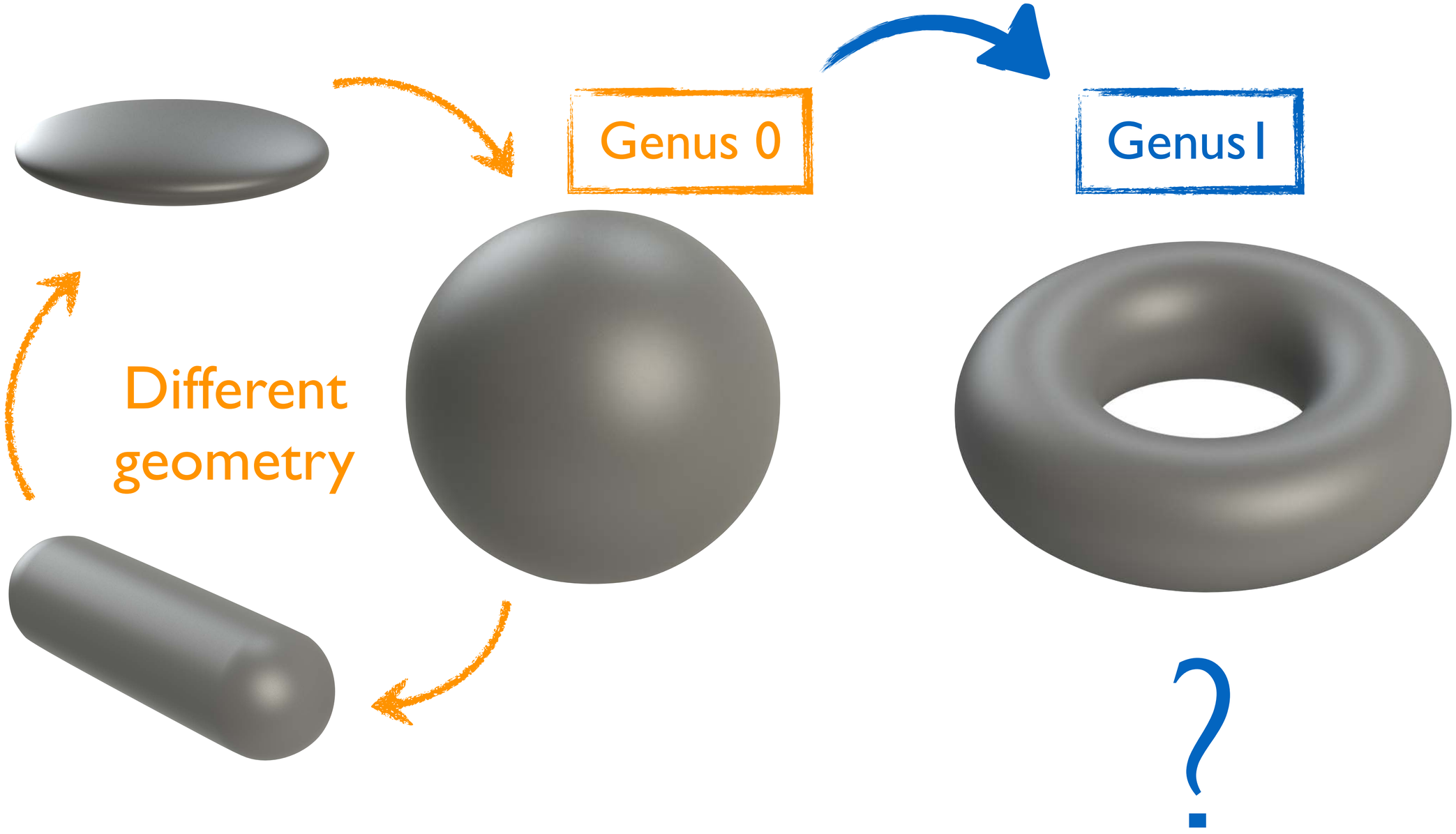

ζ = 0.25
ζ = 0.5
ζ = 1.0
ζ = 2.0
contraction
0.5
-0.5
y/D_m
-0.02
u_s/U_1
0.05

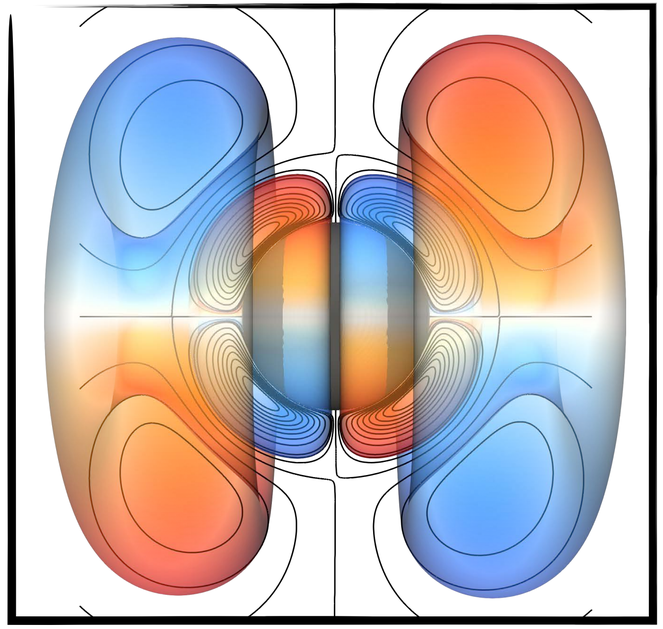

circular
profile
higher wake
velocity
streamlines
contract
Flow topology
change
bullet
profile

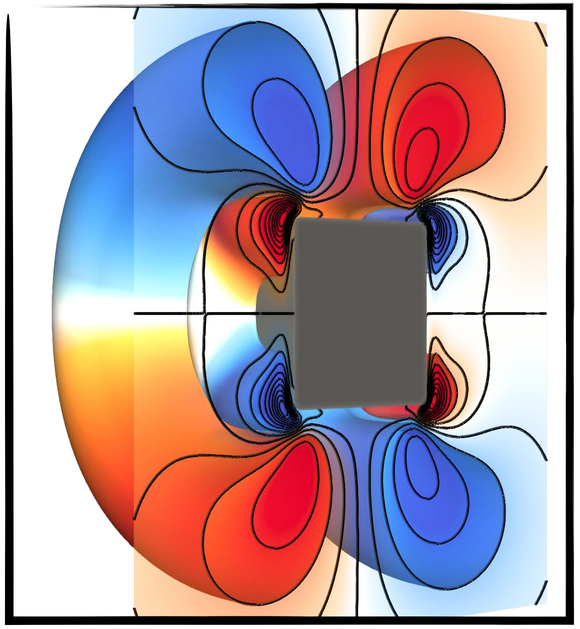

$R_0 = 28$
large DC
streaming region
Tatsuno, 1975

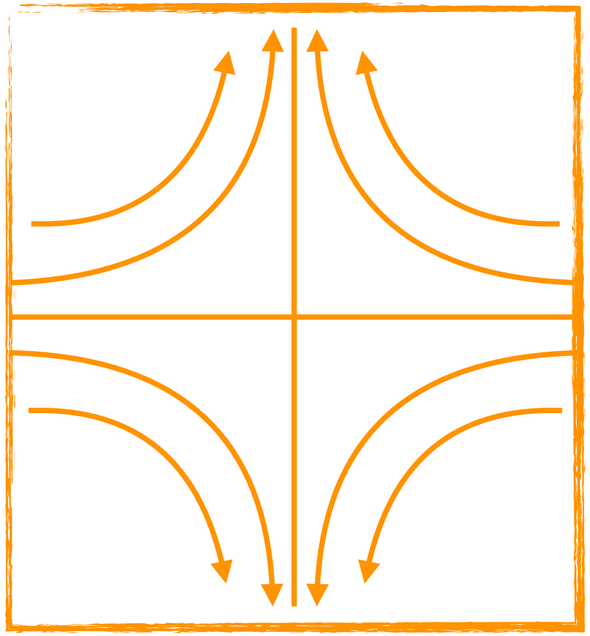


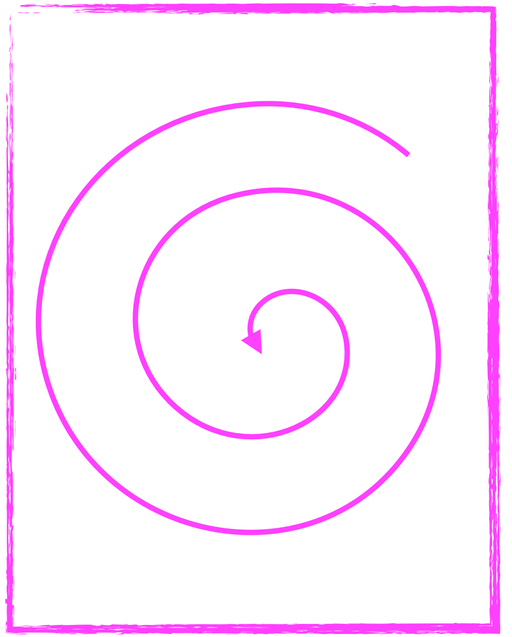

$T = 0.00$
$\zeta = 0.0$

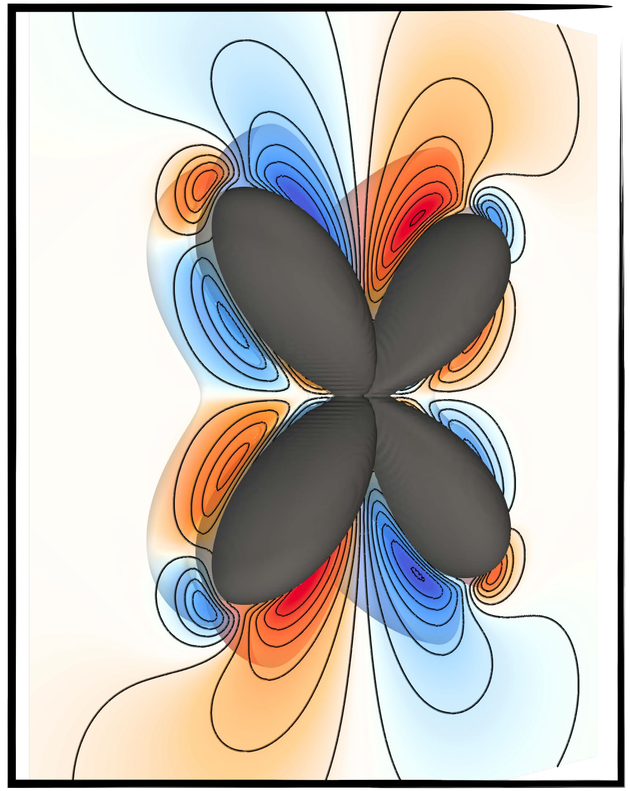

Genus 0
Genus 1
Different
geometry
?

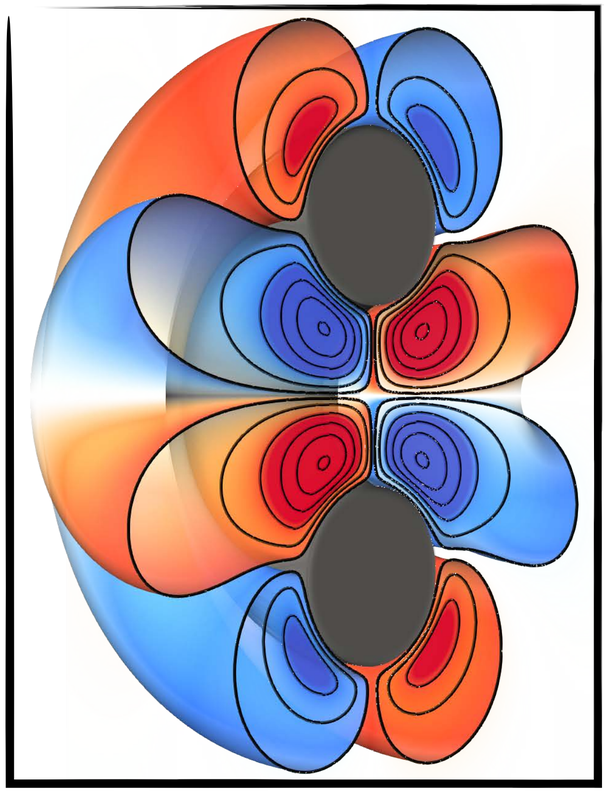


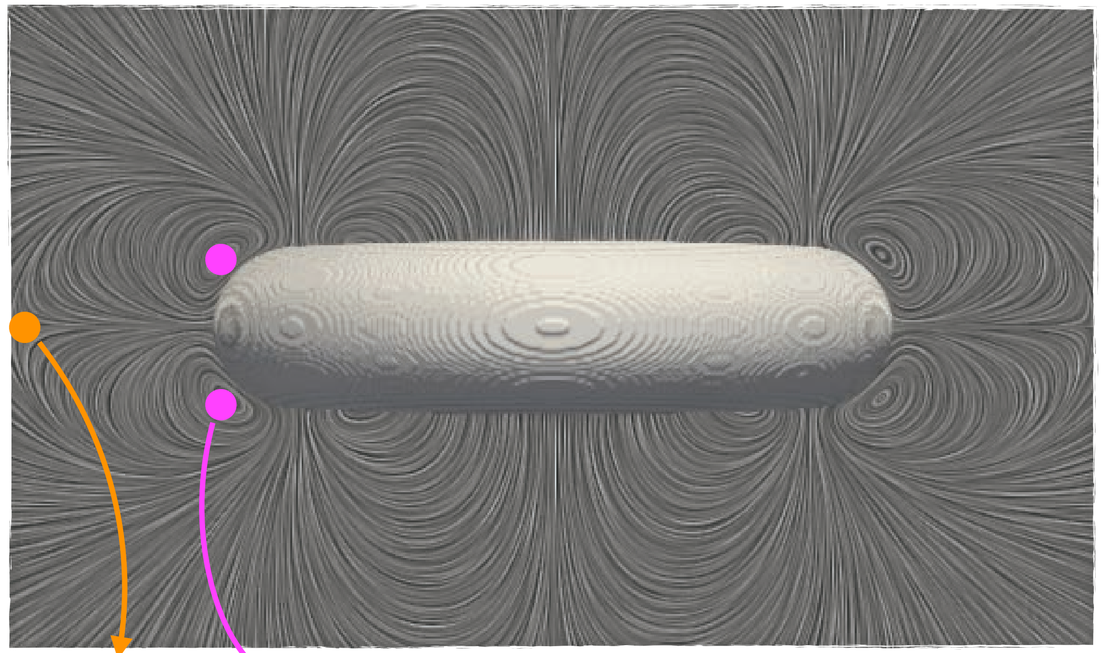


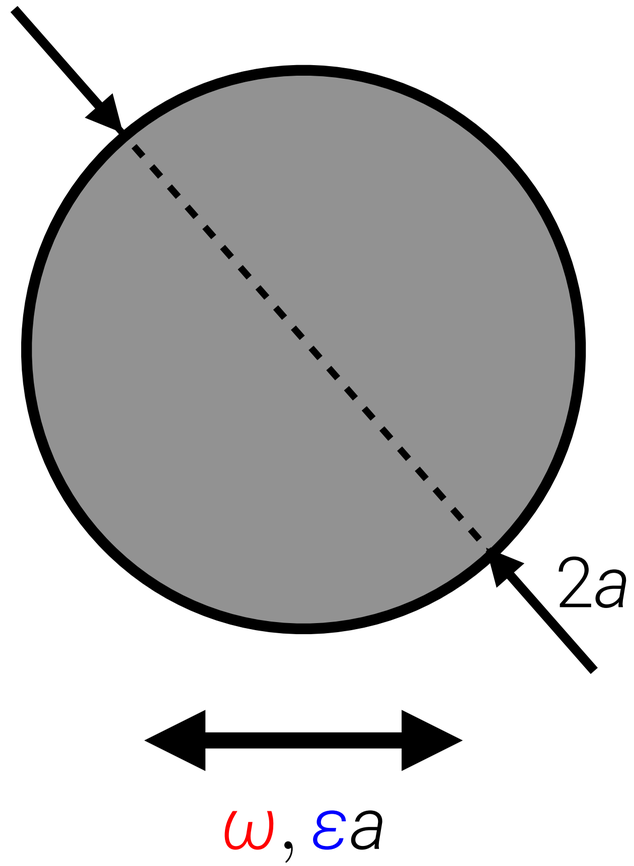


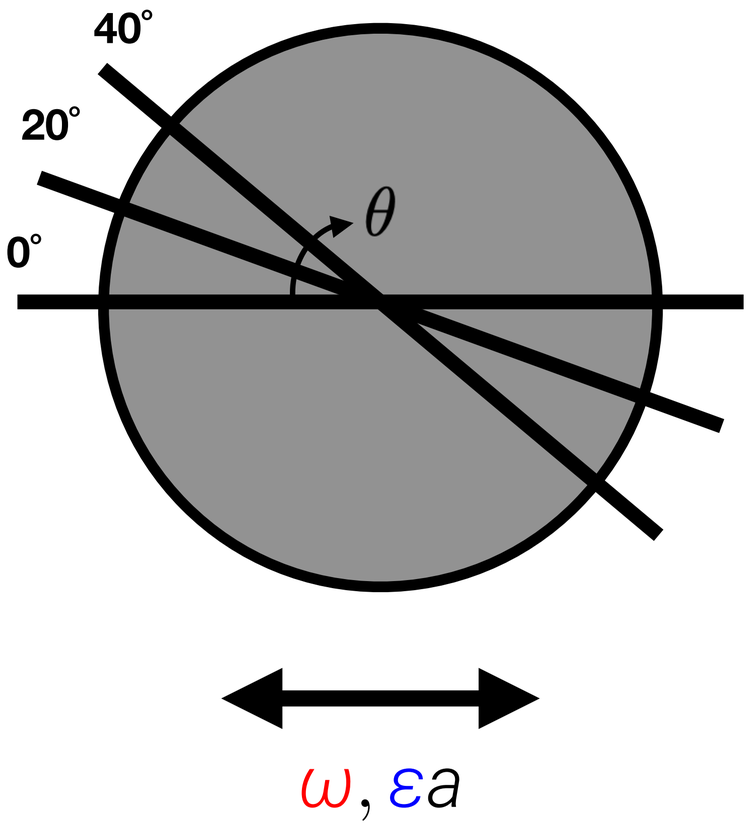


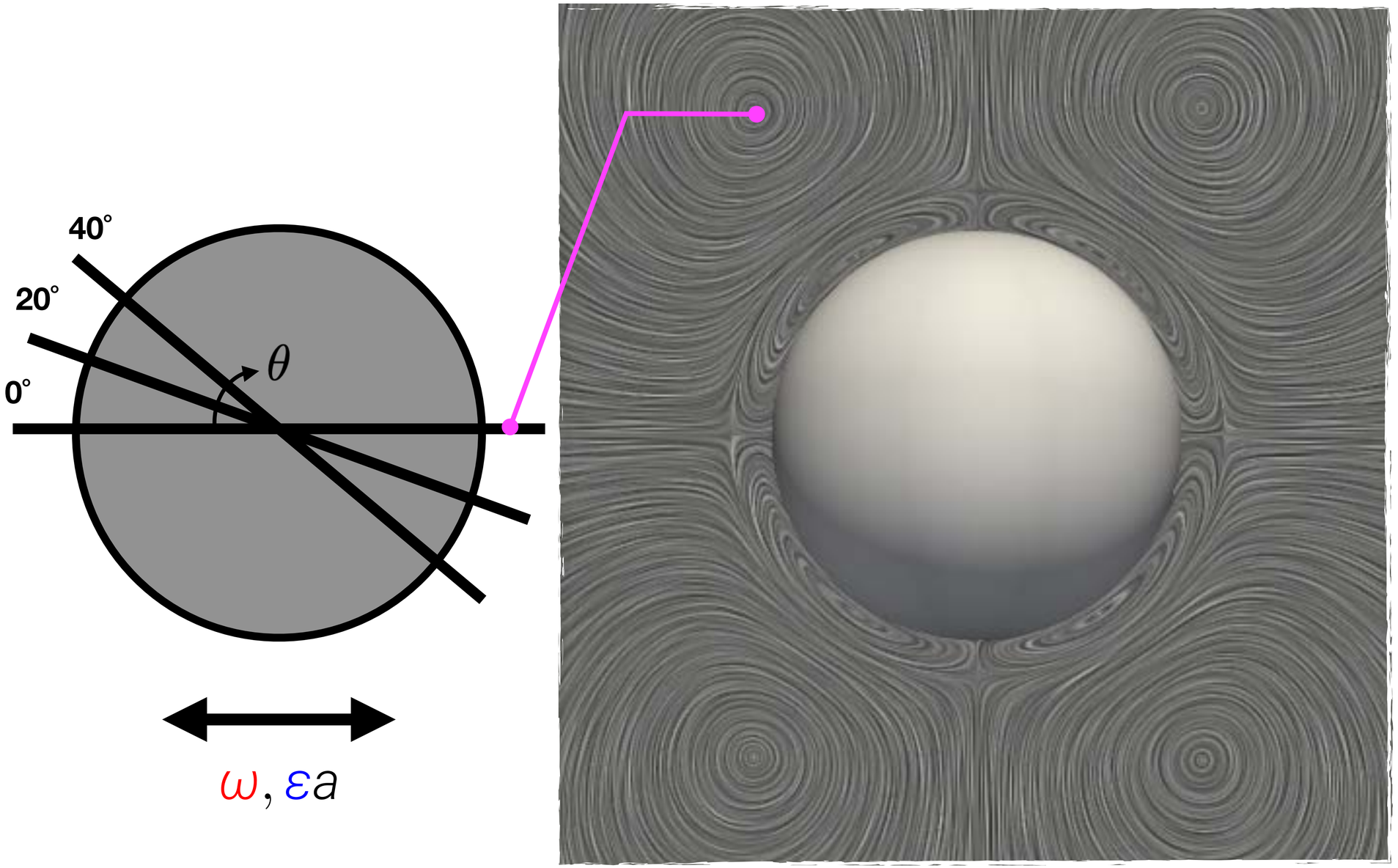


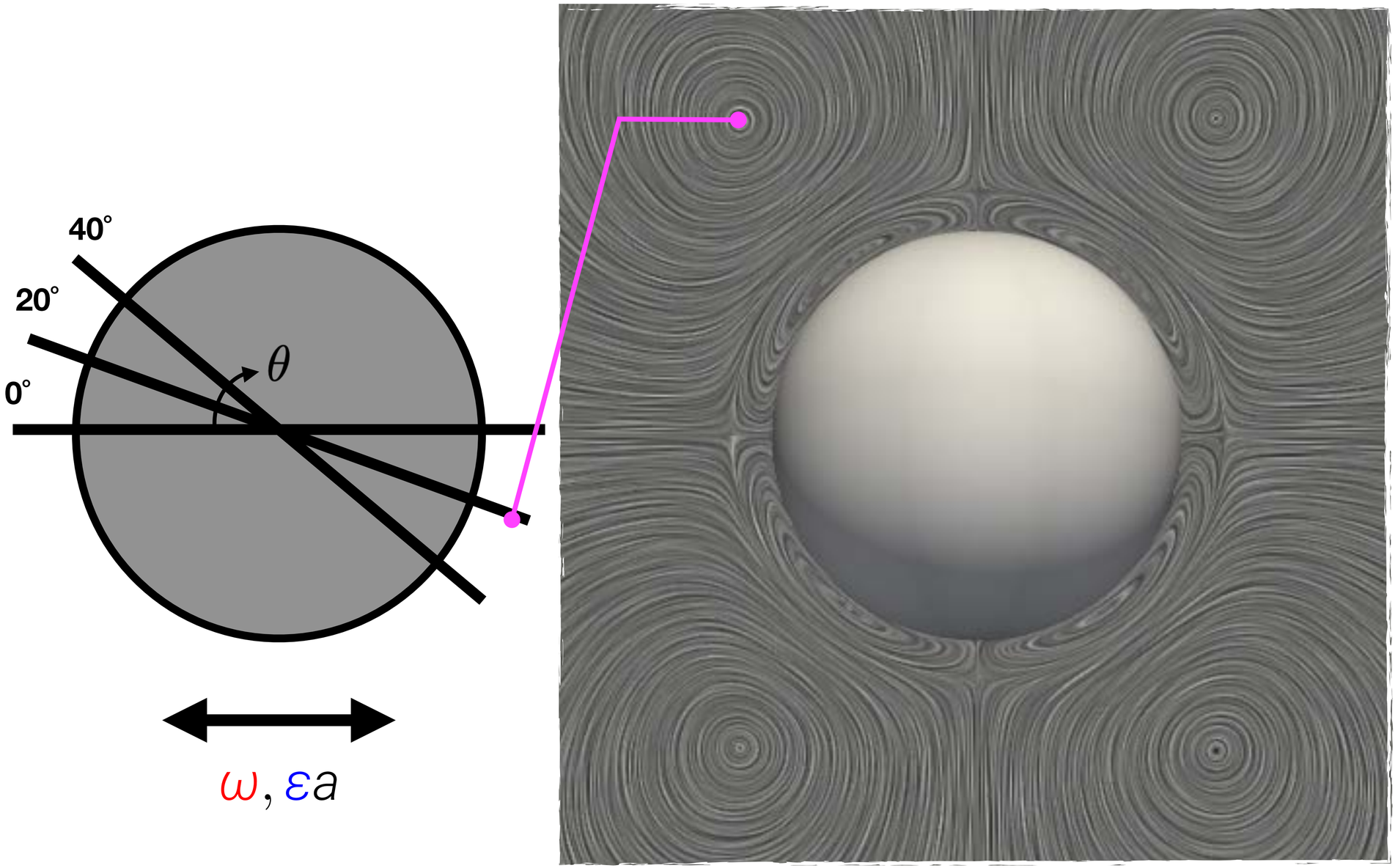


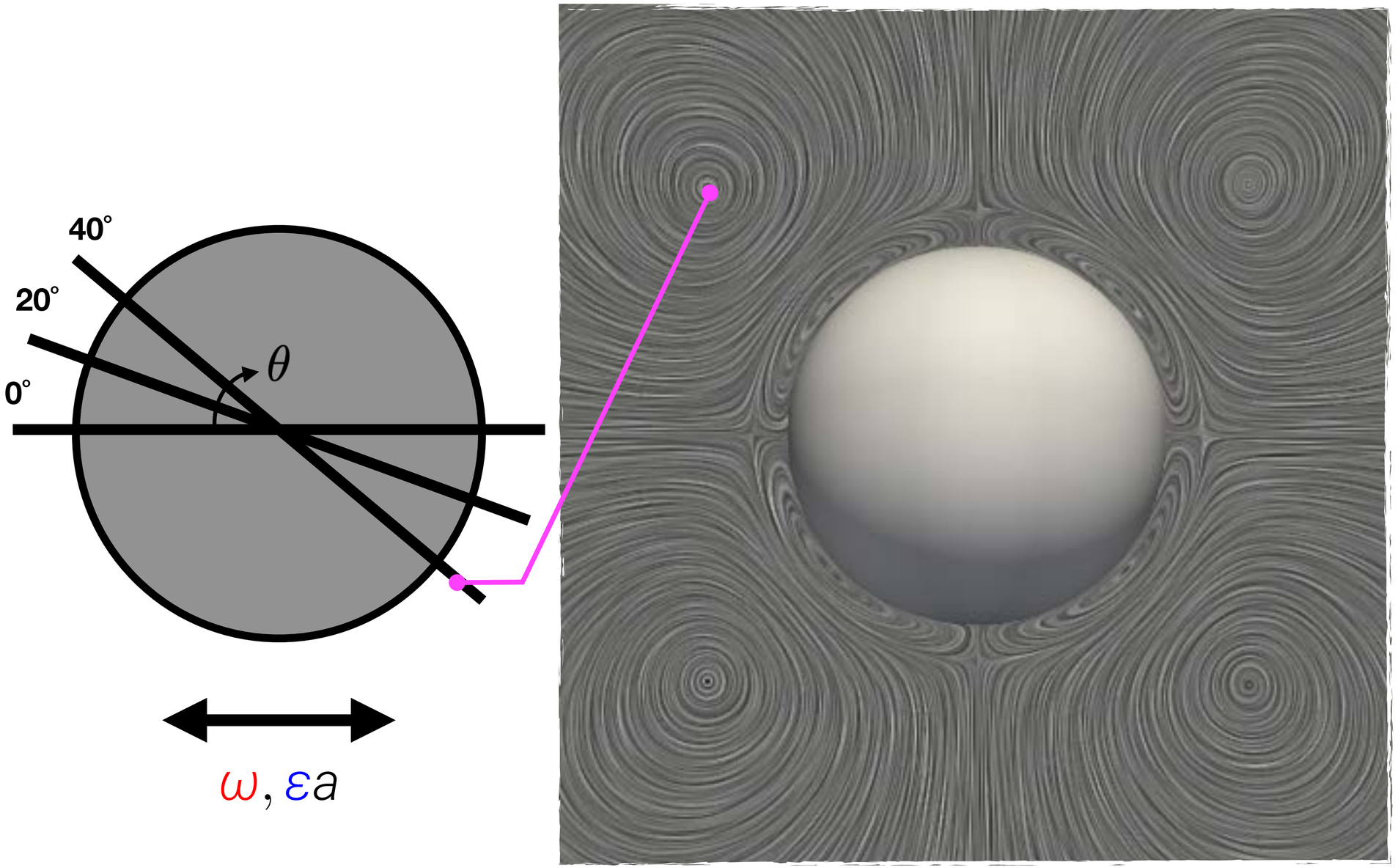

Saddle
Focus

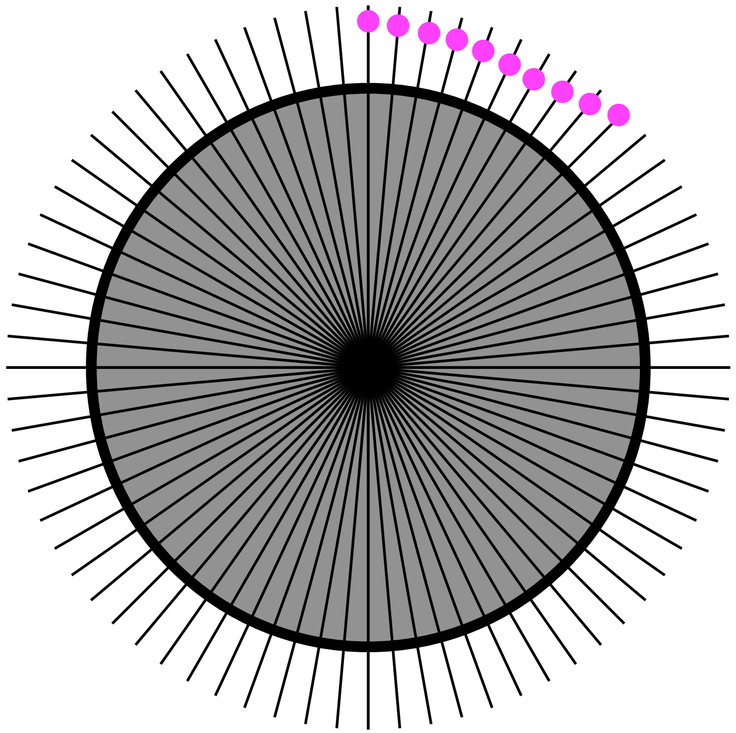

2a
ω, εa

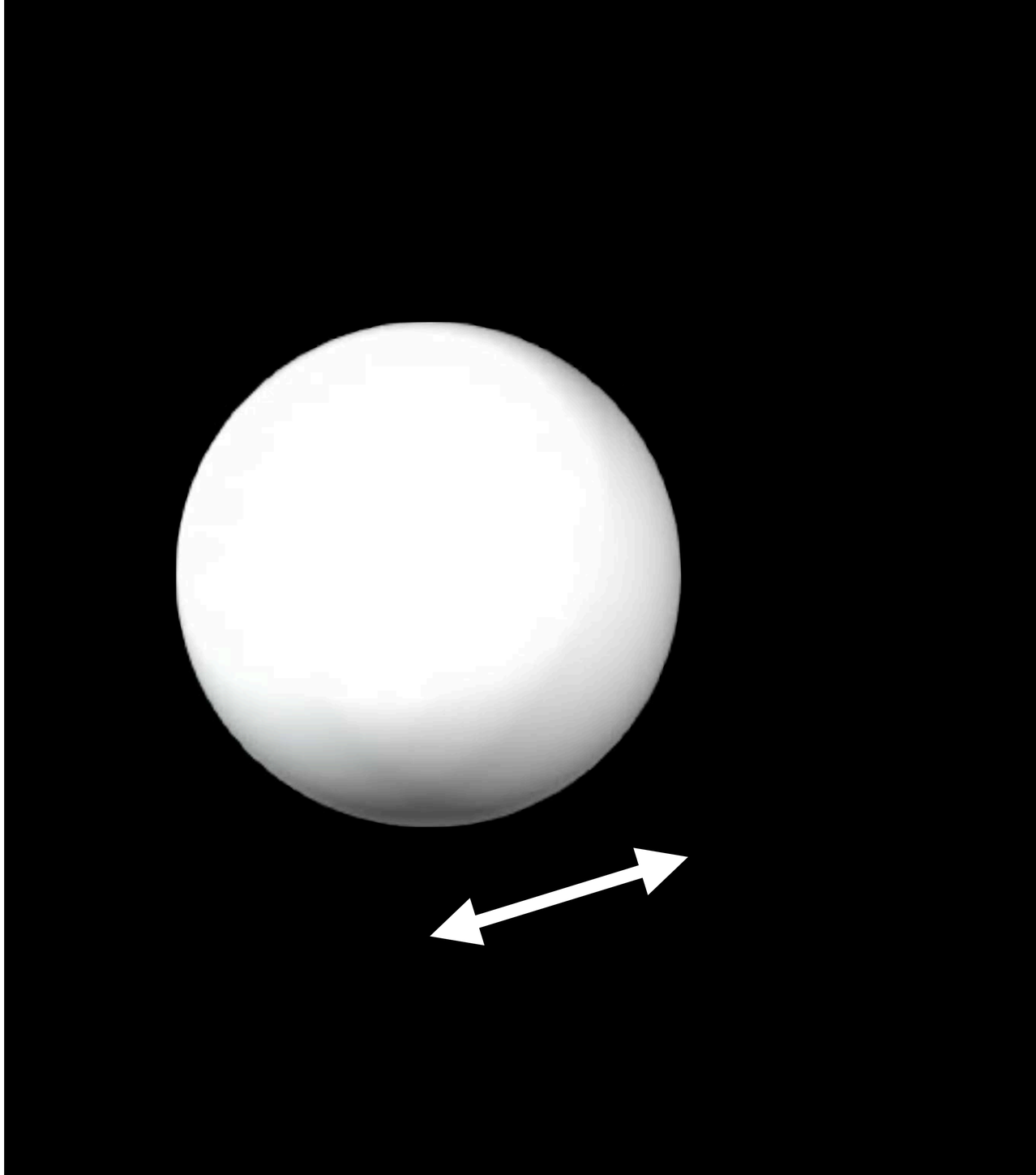

40°
20°
0°
θ
ω, εa

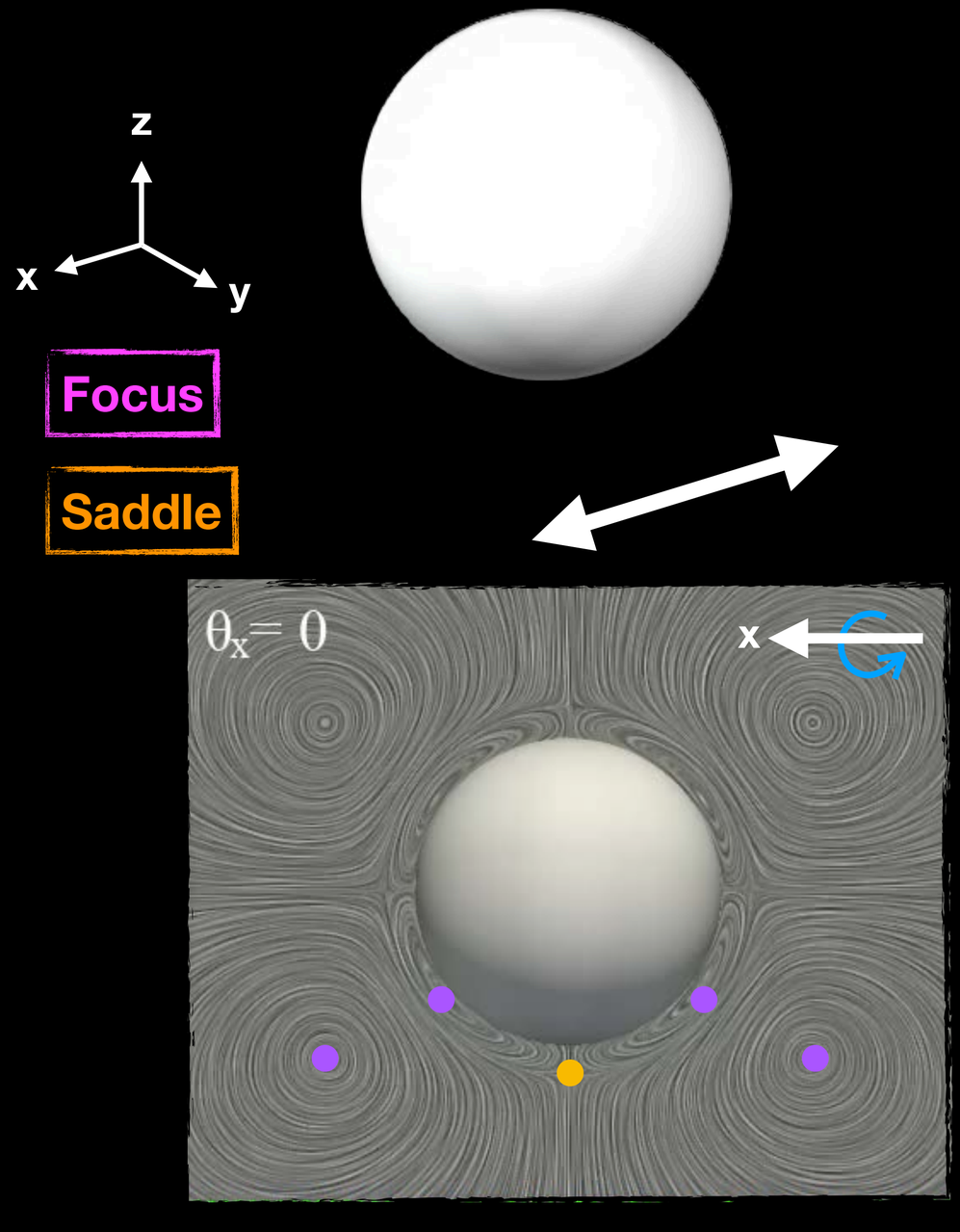

40°
20°
0°
θ
ω, εa

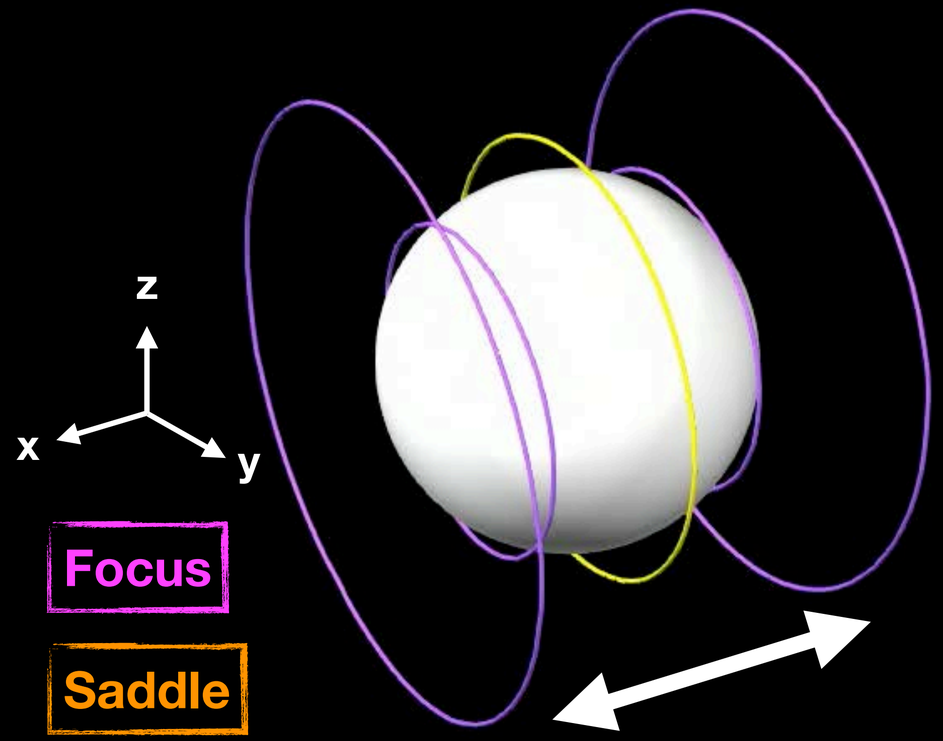

40°
20°
0°
θ
ω, εa

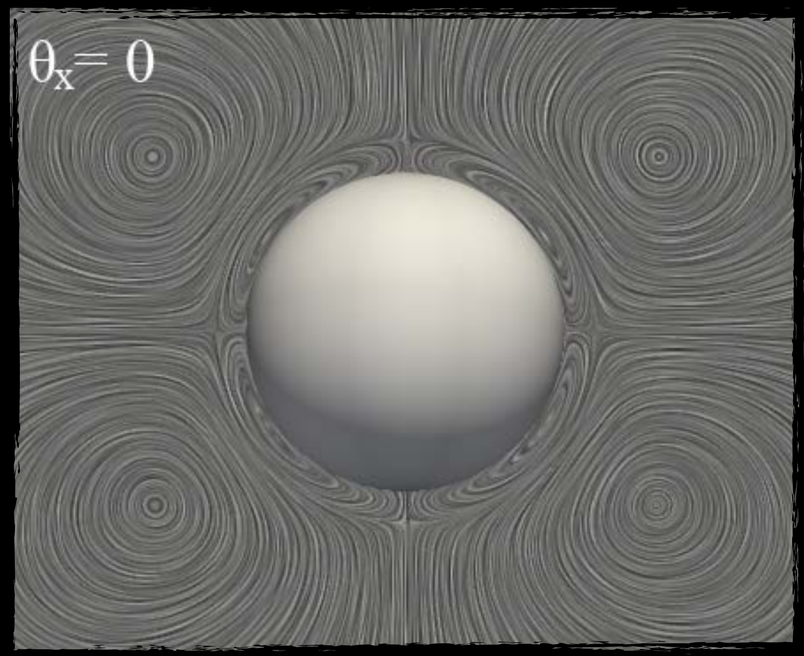

40°
20°
0°
θ
ω, εa



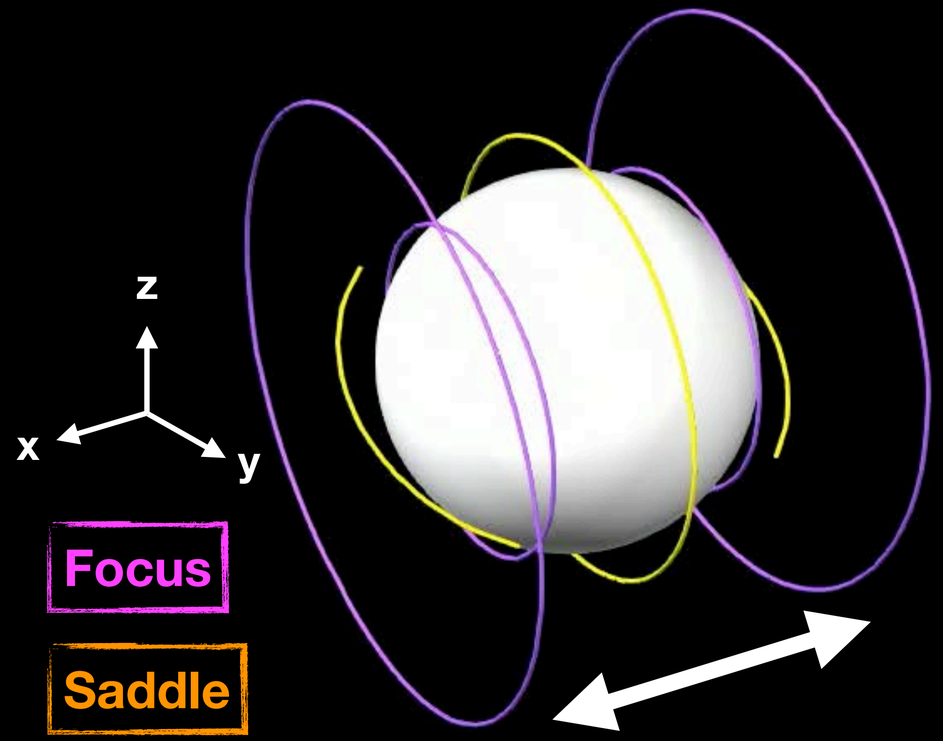


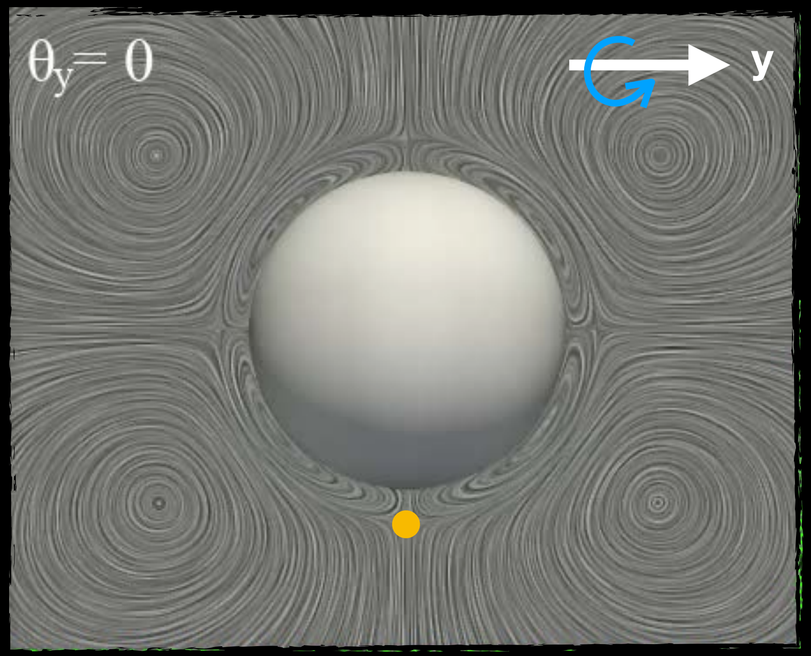

z
x
y
Focus
Saddle
$\theta_x = 0$
x


z
x
y
Focus
Saddle


$\theta_x = 0$

$\theta_z = 0$
z


z
x
y
Focus
Saddle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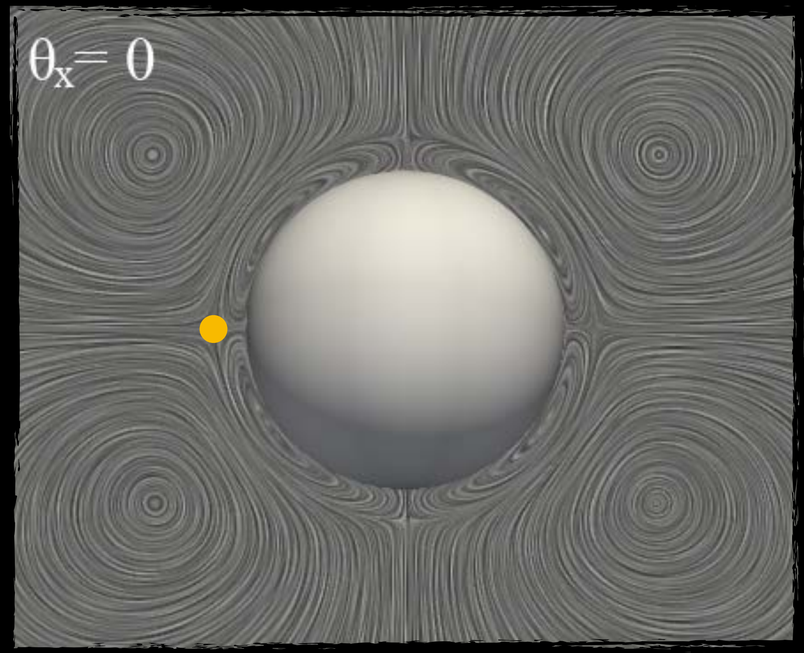
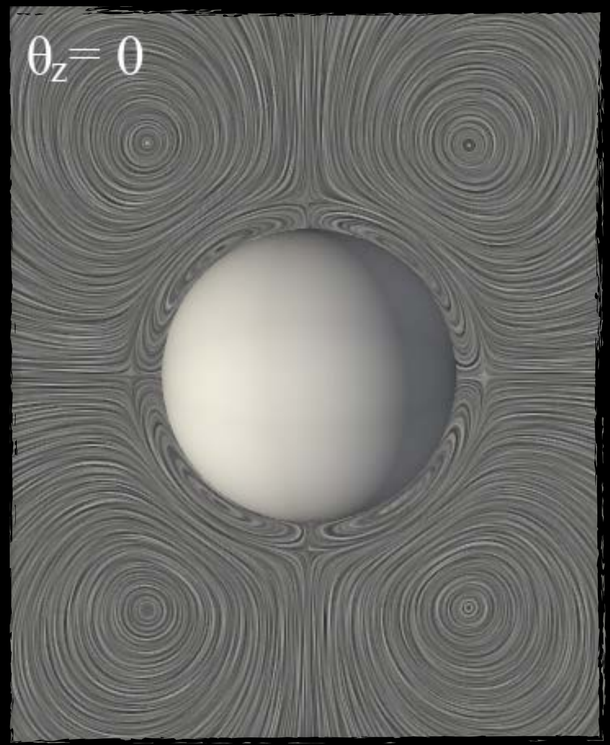
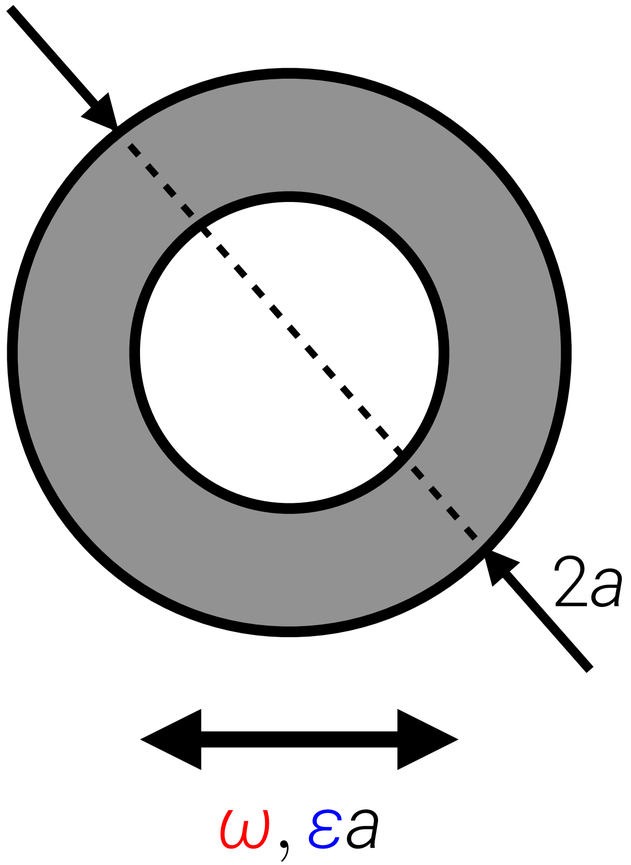
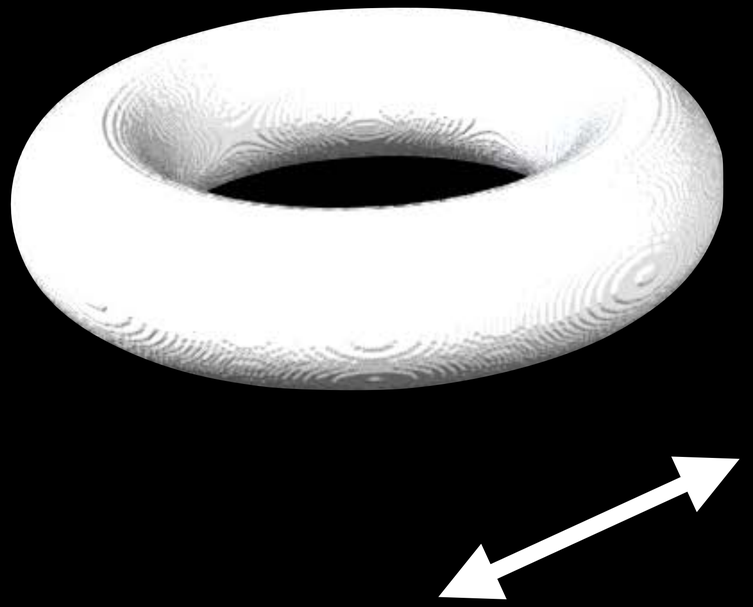
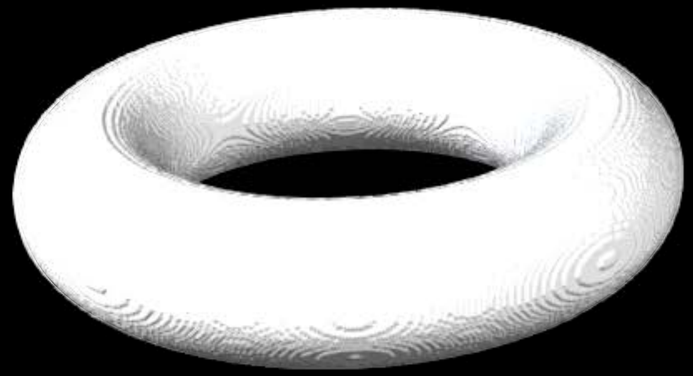
y


$\theta_x = 0$


$\theta_z = 0$

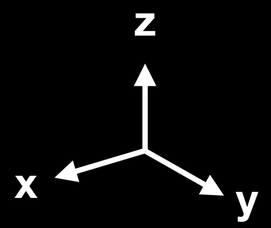

2a
ω, εa

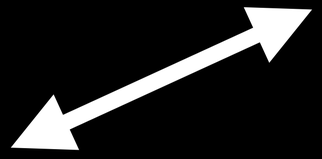


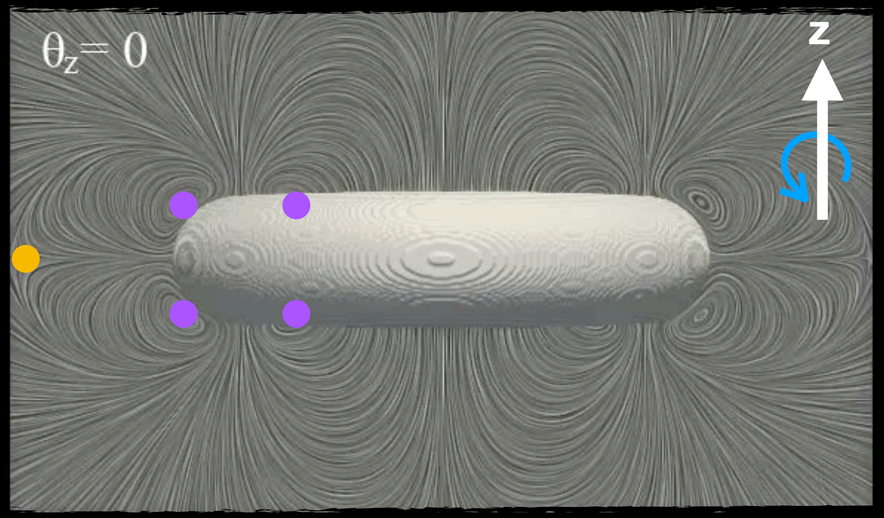


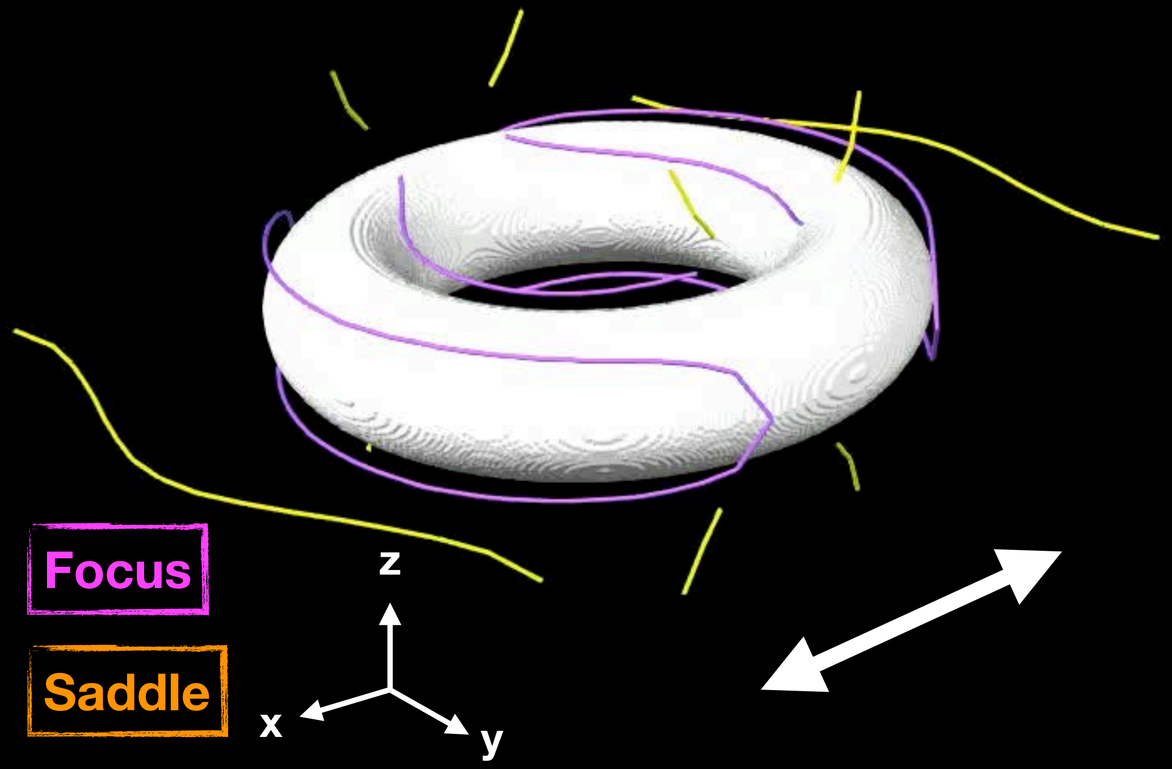
Focus

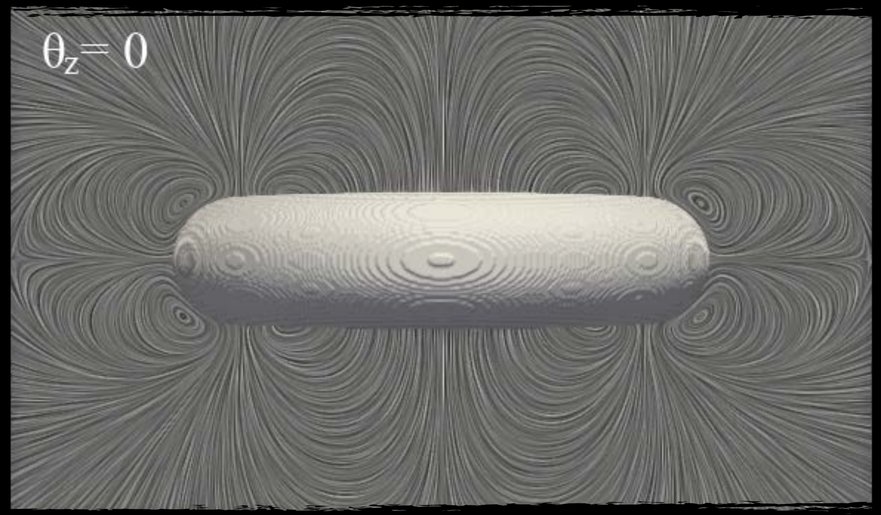
Saddle








Focus
Saddle
z
x
y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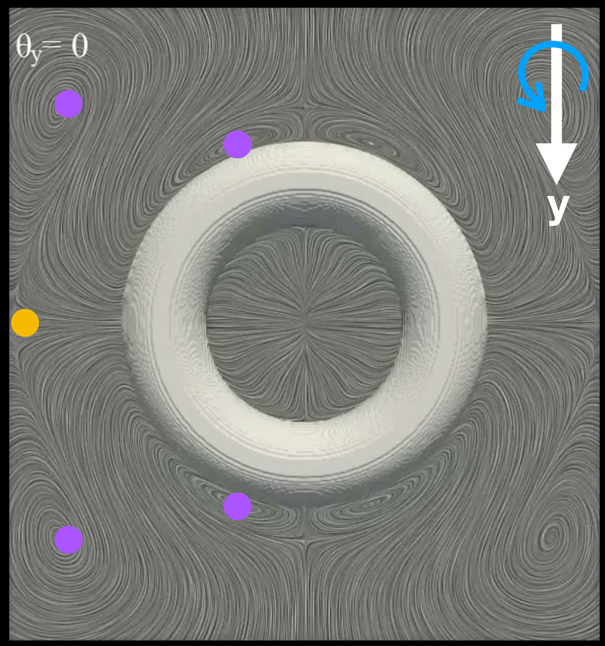
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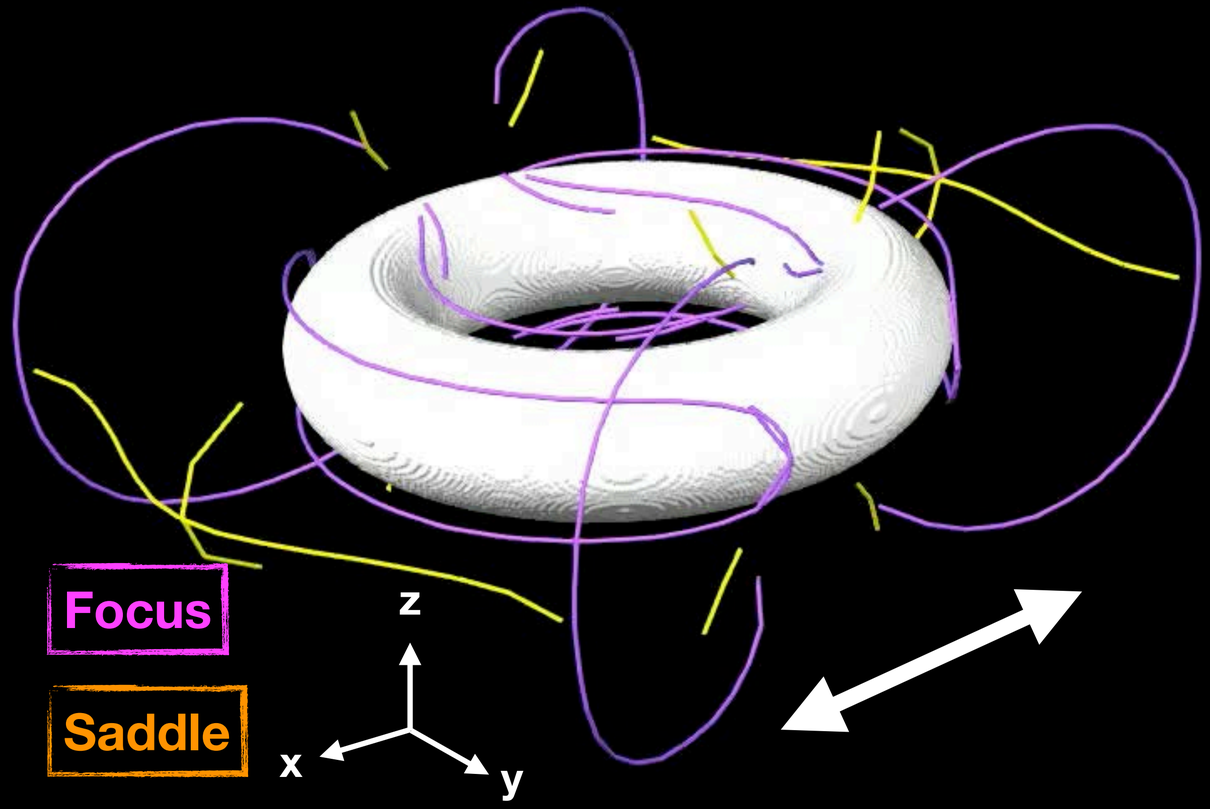
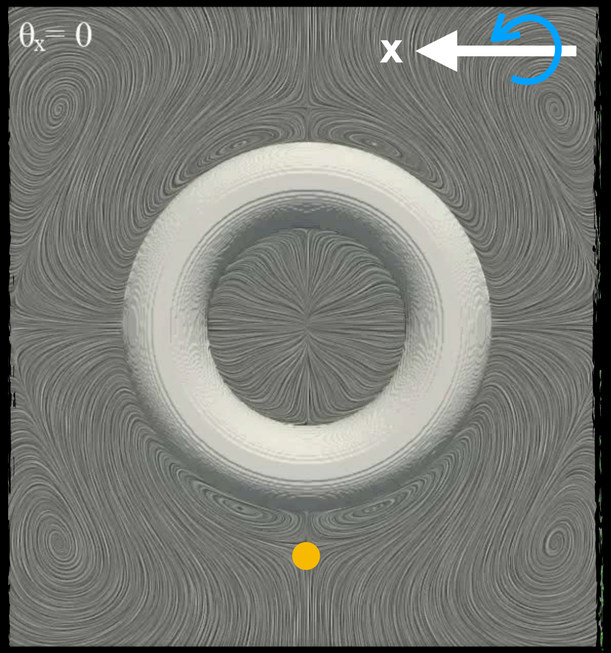

Focus
Saddle
z
x
y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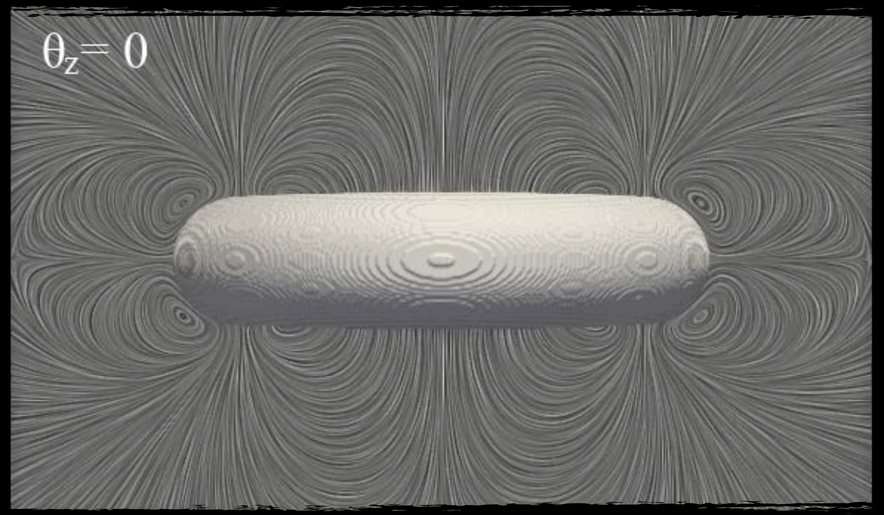
x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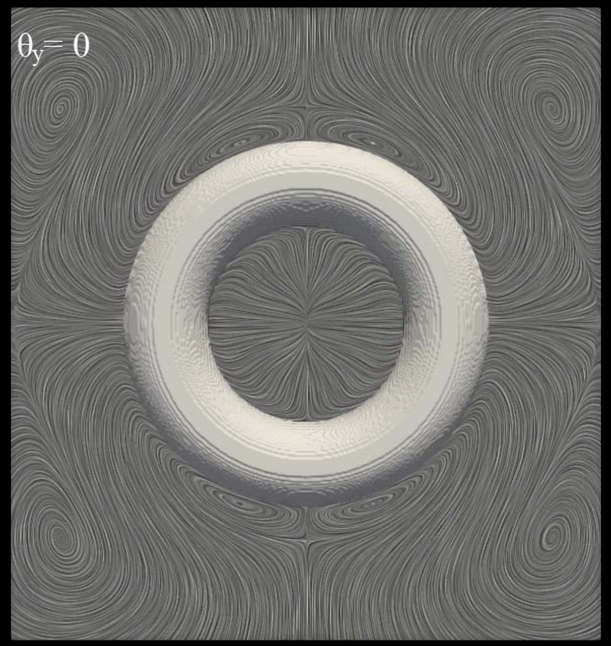
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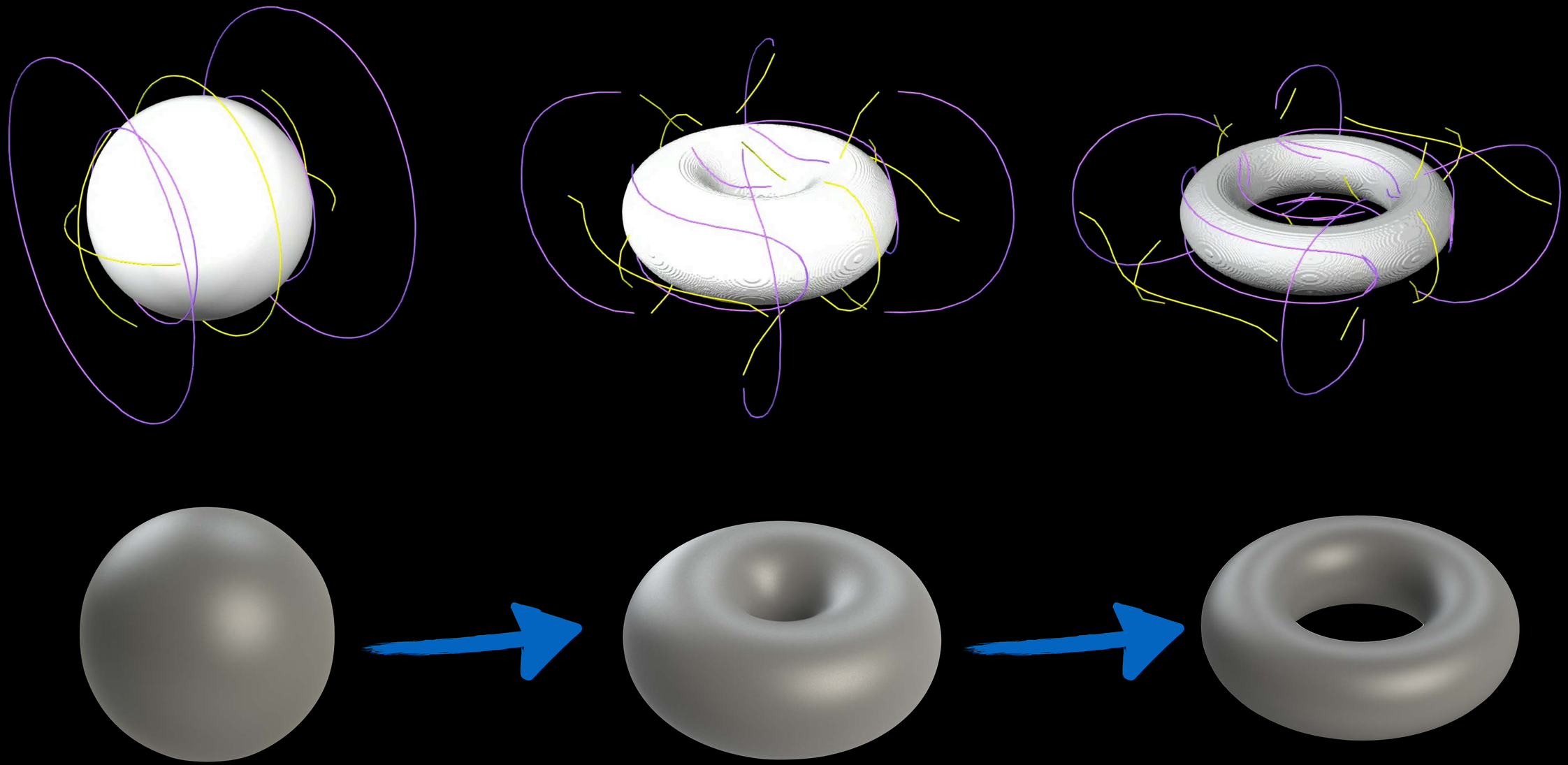

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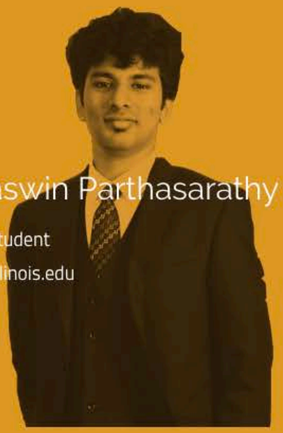

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