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A hydrodynamic toy model for fish locomotion

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0. State of the art

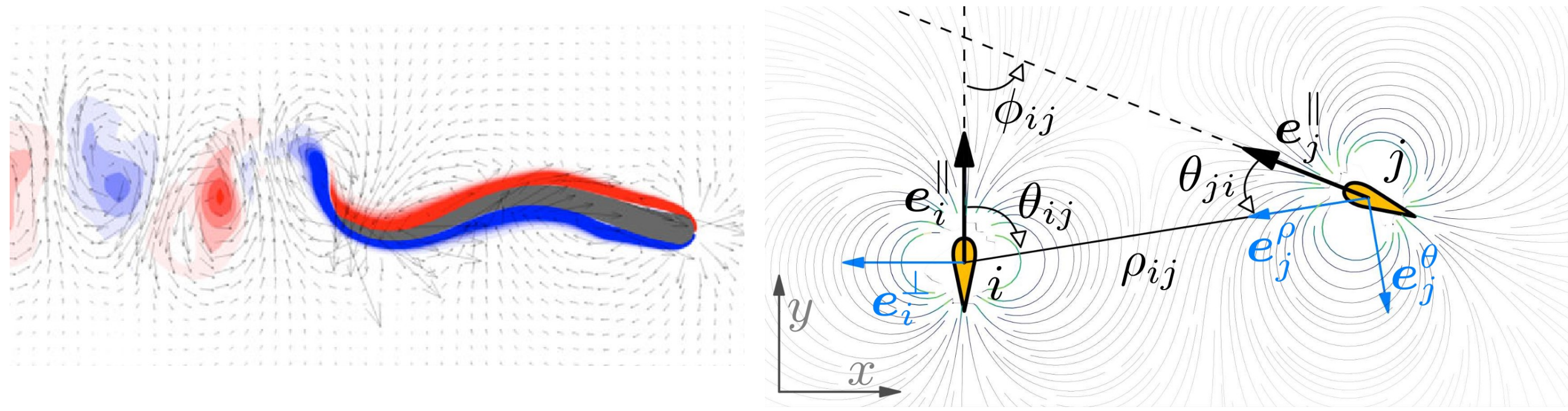
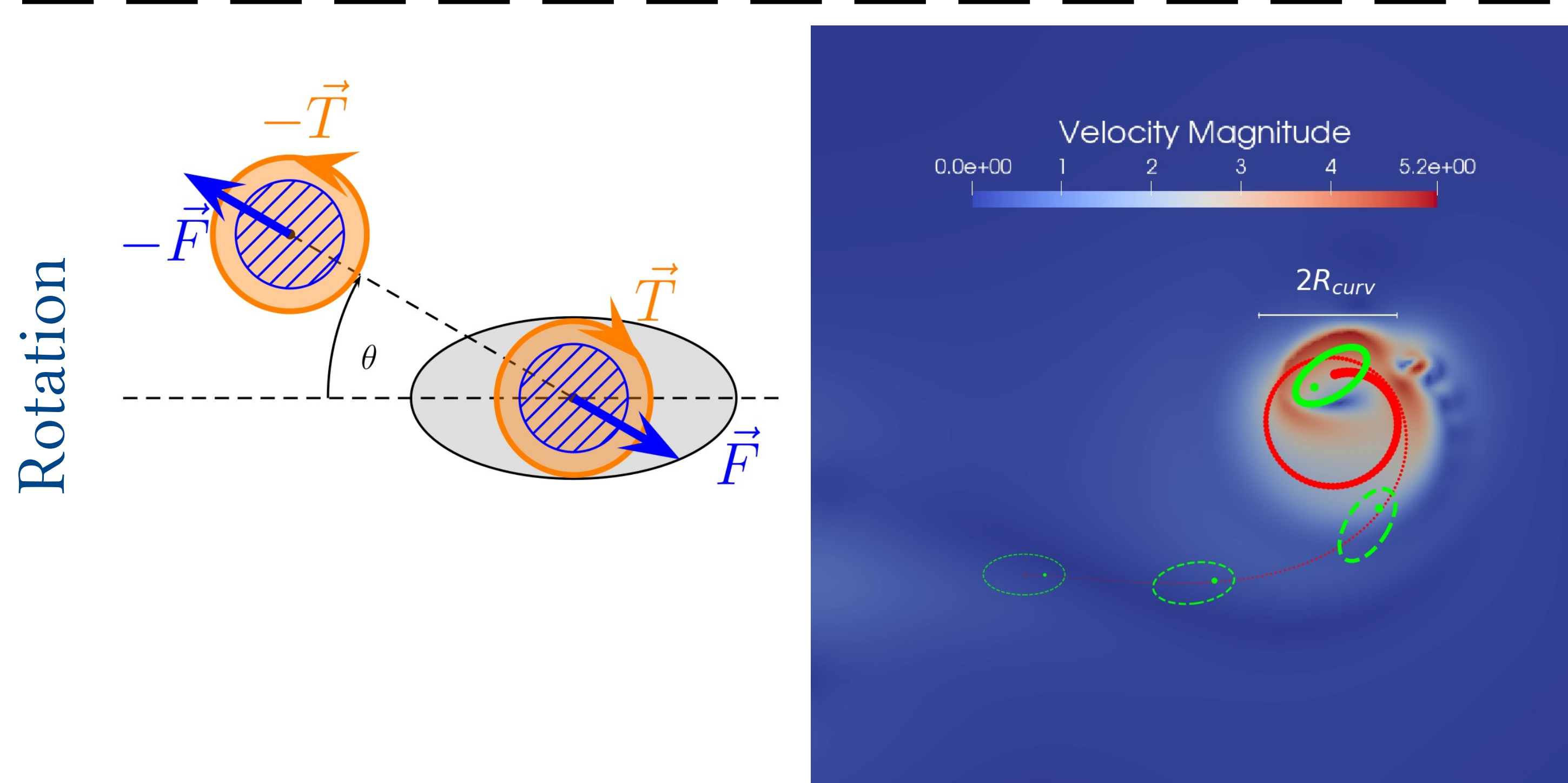
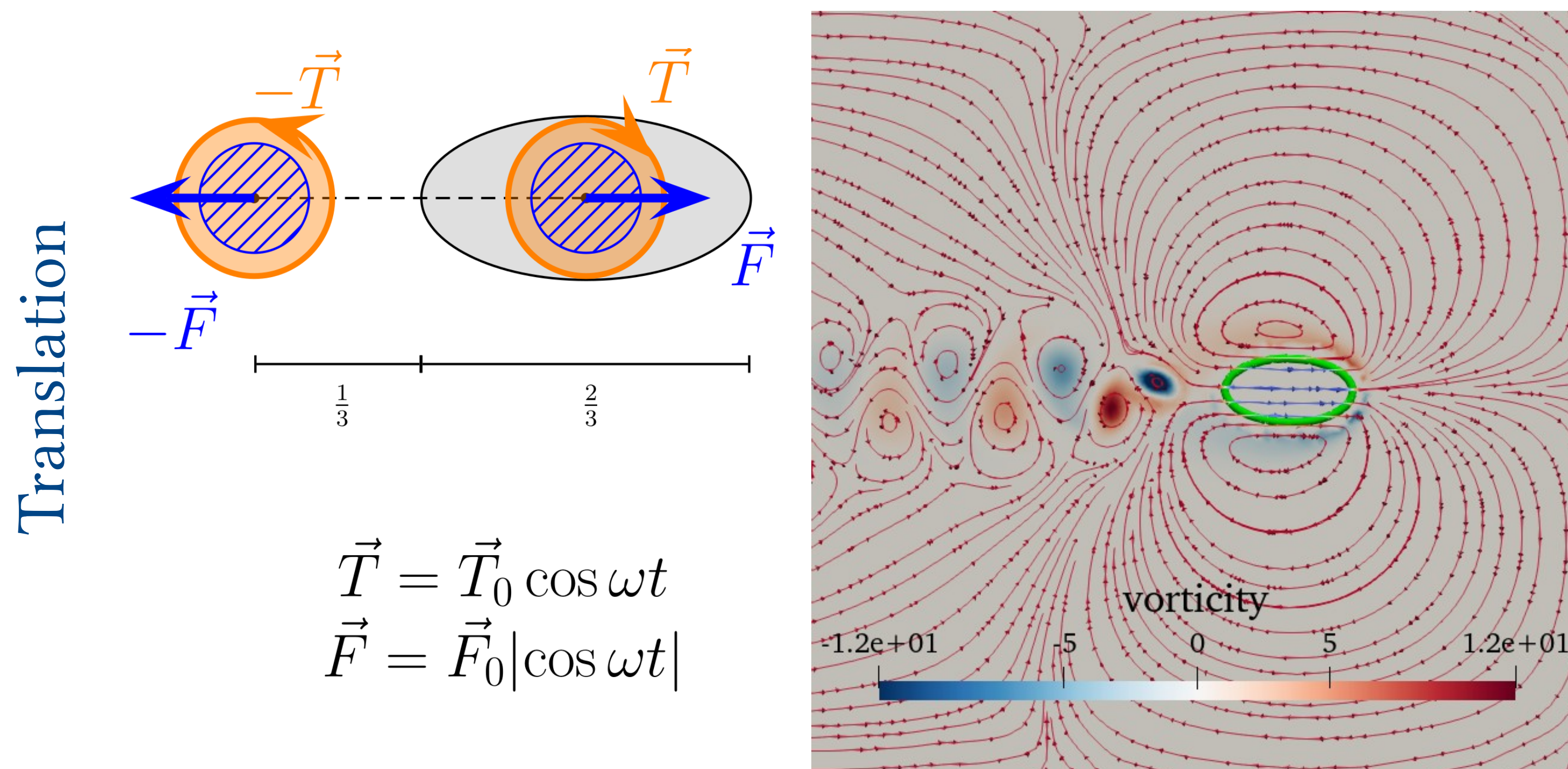


Figure: Left. Numerical velocity field of a swimming fish taken from [Kern06]. Colors correspond to the vorticity field. Right. Illustration of the dipole field and the interaction used in [Fillela18] to study the hydrodynamic interaction in collective fish behavior .

I. The toy model definition

- The fish is defined a rigid body with a ellipsoidal shape
- The rigid body is defined by a penalization in viscosity: $\frac{\mu_{Rigid\ Body}}{\mu_{Fluide}} = 10^6$
- The tail flapping is described by local forces directly applied in the Navier-Stokes Eq.

$$\rho \left(\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla) \vec{v} \right) = -\nabla p + \nabla \cdot \left(\mu \frac{\nabla \vec{v} + \nabla \vec{v}^T}{2} \right) + \sum_i \vec{F}_{Torque}^i + \sum_i \vec{F}_{Dipole}^i$$
- Solved using FEEL++ [1], a finite element C++ library.
- Control parameters are: the torque T_0 , the force F_0 and the pulsation ω .



A hydrodynamic toy model for fish locomotion



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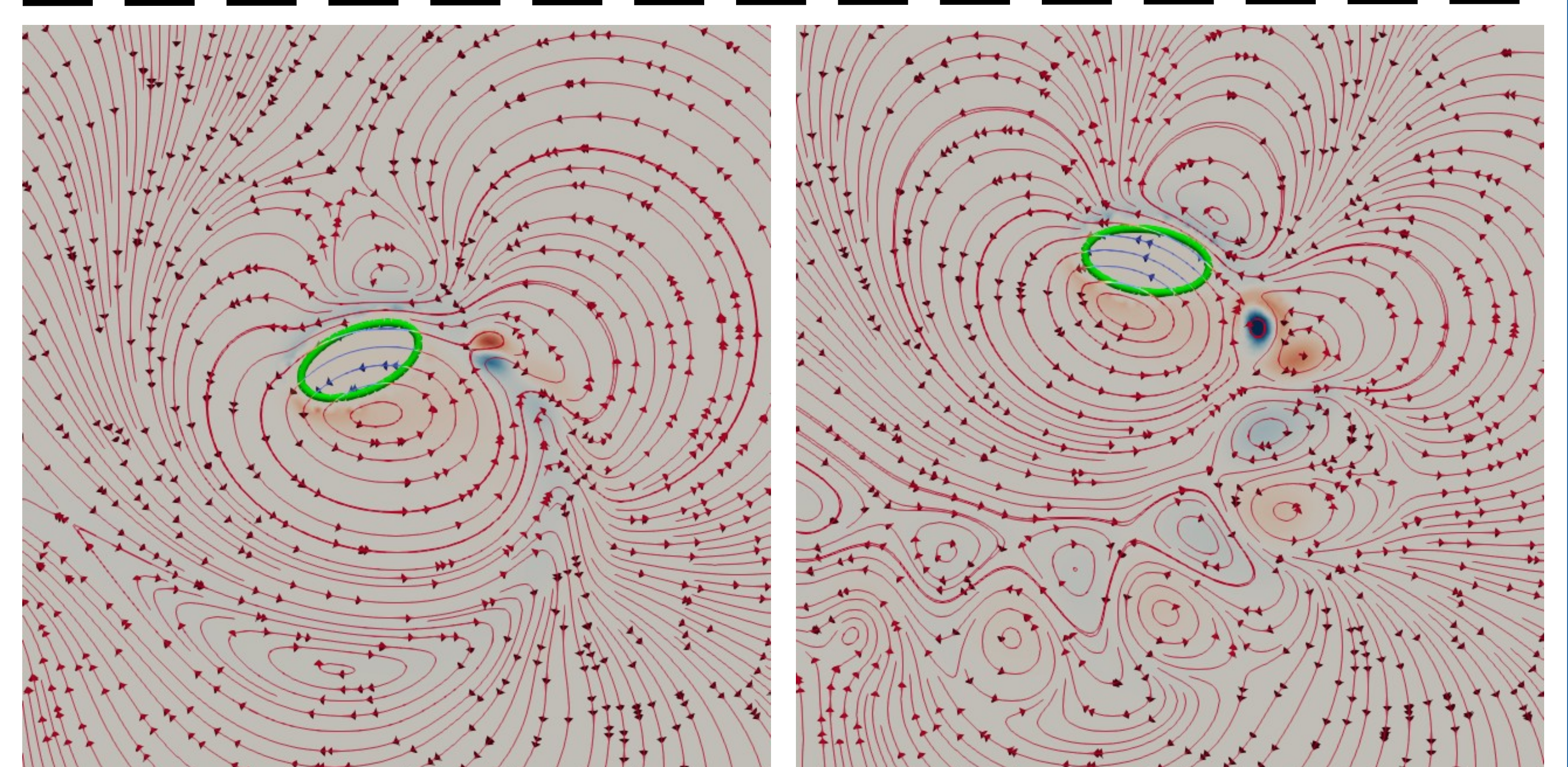
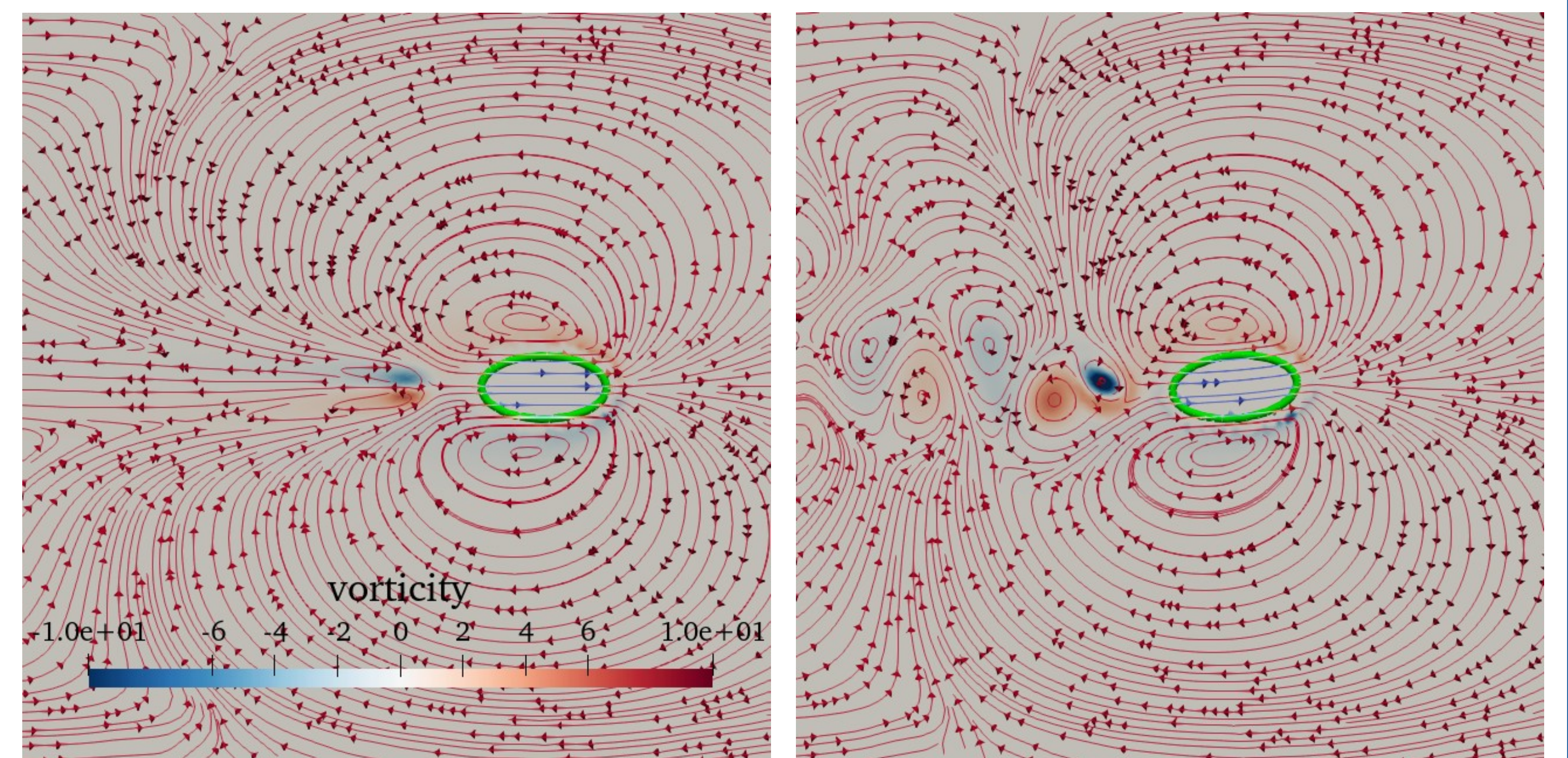
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II. Velocity field

Re=60, $F_0=150$

No Torque $T_0=0$

With Torque $T_0=450$



III. Tuning the behavior

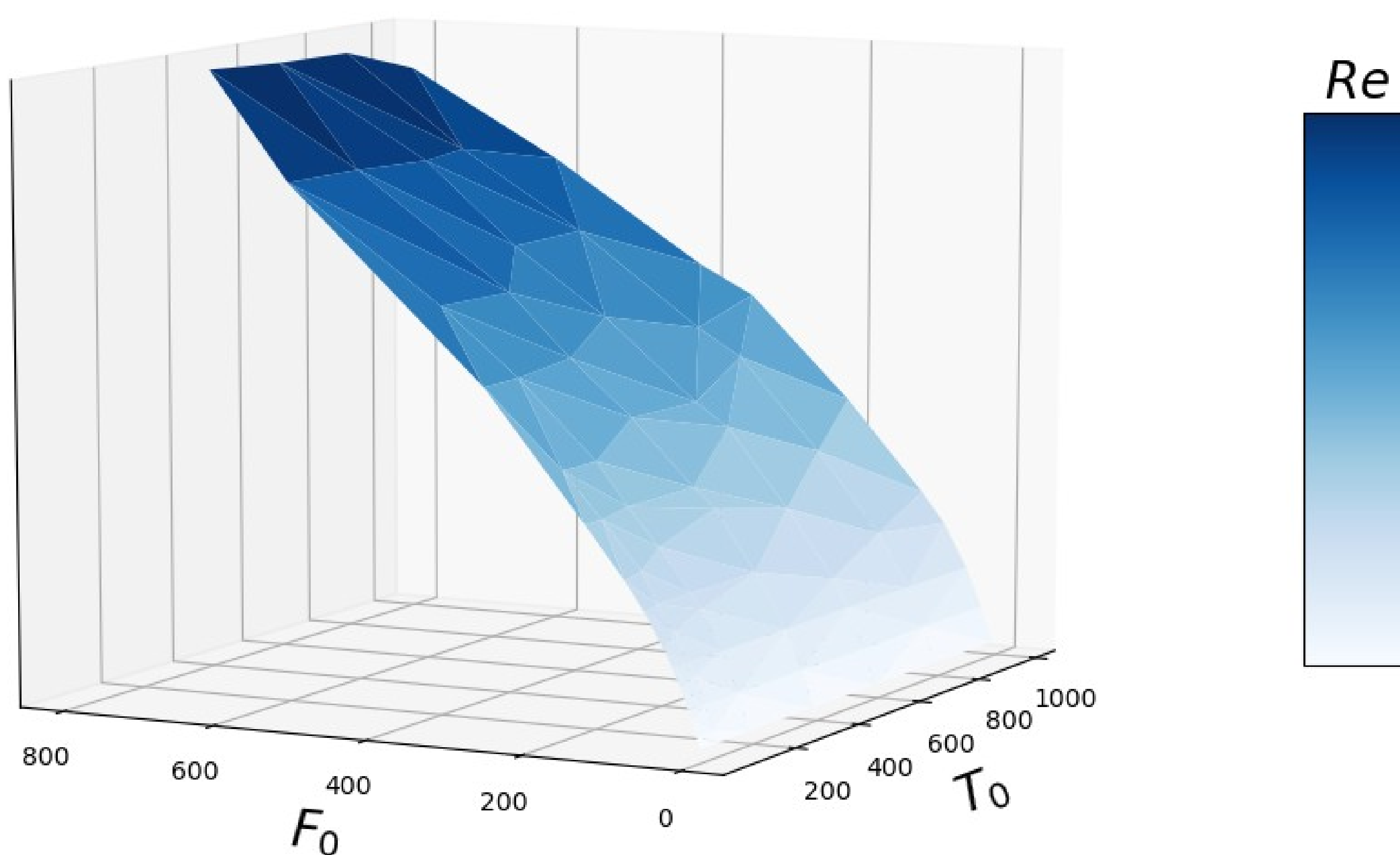


Figure: Re number as a function of the dipole amplitude and the torque amplitude. The virtual tail is in the neutral position ($\theta=0$)

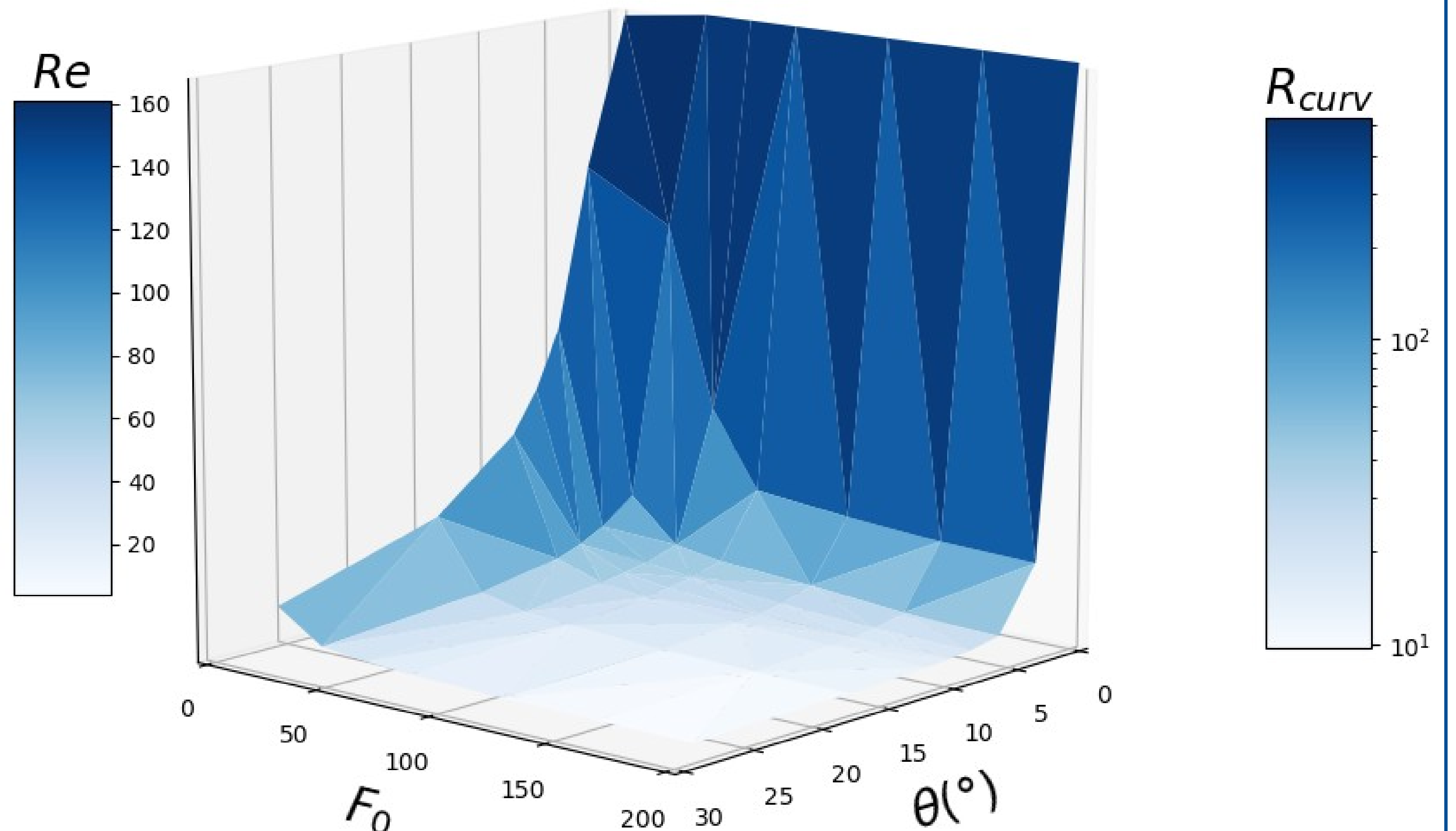


Figure: Radius of curvature as a function of the dipole amplitude and the shift of the virtual tail position. The torque amplitude is fixed $T_0=450$.

[Kern06] Kern S., Koumoutsakos P., Simulations of optimized anguilliform swimming, J. Experimental Biology, 209, 4841-4857, 2006

[Fillela18] Audrey Fillella, Francois Nadal, Clément Sire, Eva Kanso and Christophe Eloy. Model of collective fish behavior with hydrodynamic interactions. Physical Review Letters, May 11, 2018

[1] <https://github.com/feelpp/feelpp>

Conclusions

- We manage to reproduce and control the amplitude of the vortex wake behind a fish with a minimal model
- Next steps are:
 - Do the link between ω and T_0 , F_0 to convert social parameters into force parameters
 - Check the scaling of the Re as a function of ω