Soluto-capillary propulsion of Marangoni boats

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1. Introduction

We study the propulsion of small objects on the surface of the water, which are called Marangoni boats. Many studies have been conducted on such objects with camphor boats [1] However, we can obtain controlled Marangoni flows by using soluble ionic surfactants (TTAB, DeTAB,...)[2],[3]. In this study we are interested in the effect of the solubility of surfactants during the propulsion of Marangoni boats. The boats are composed of a plastic floater and a reservoir: a strip of paper soaked in soluble surfactant glued by capillarity to the back of the floater. When deposited on the surface of a milipore water tank, the surfactant is released at the back generating a difference of capillary force between the bow and the stern. The boat is then propelled forward.

2. Experimental setup

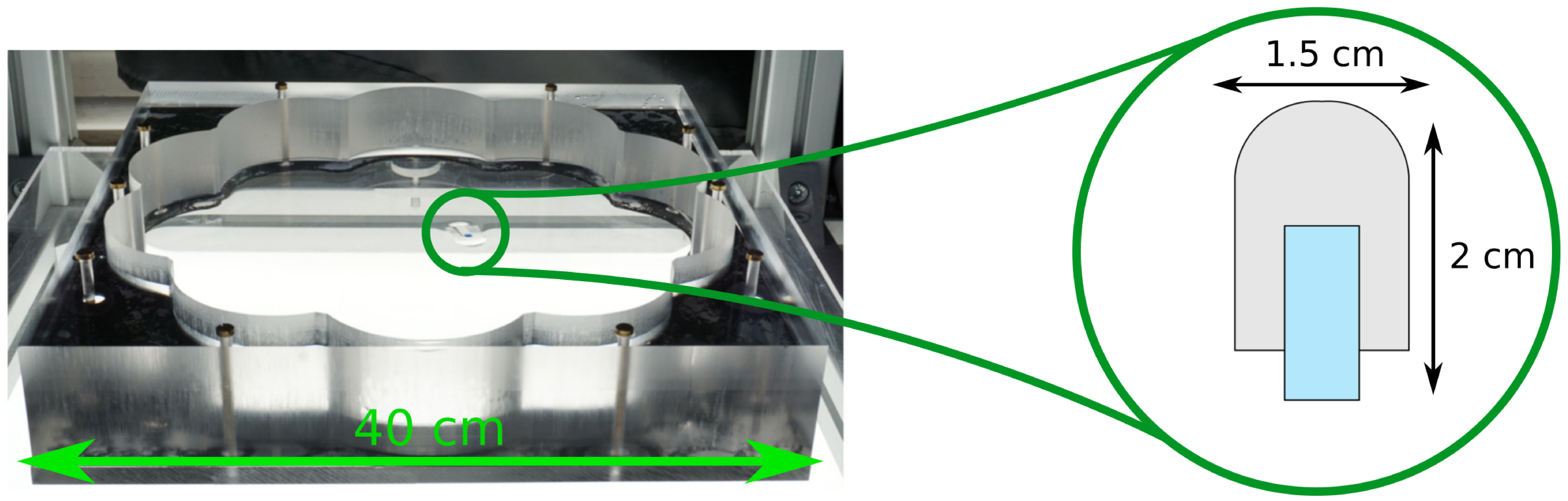


Fig. 1. Experimental setup

3. Tracking of the boat

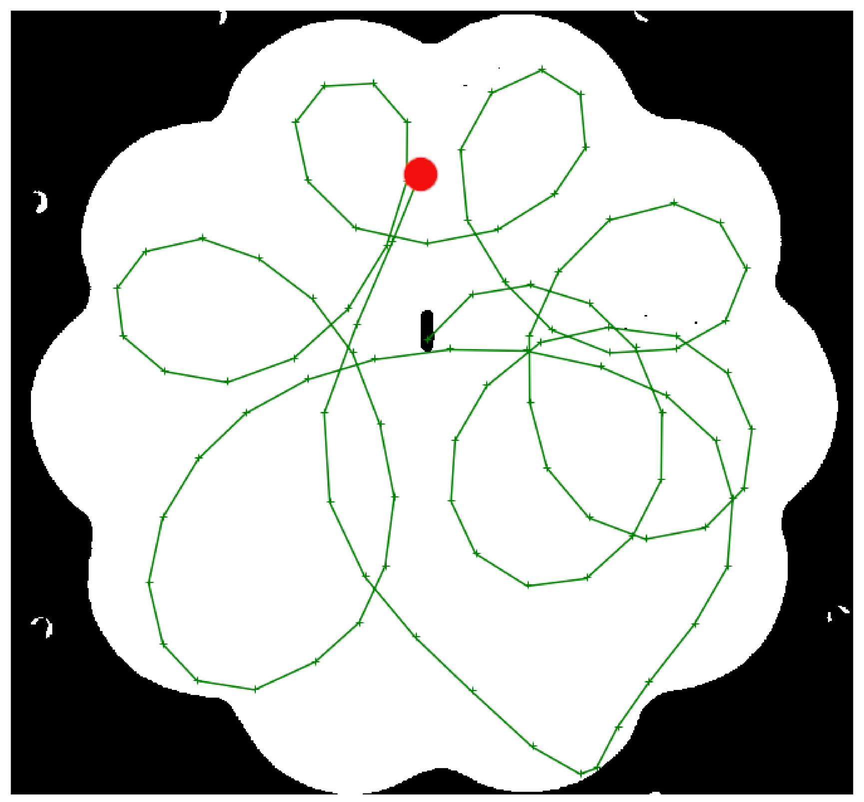


Fig. 2. Tracking of the boat is performed by a python algorithm trackpy

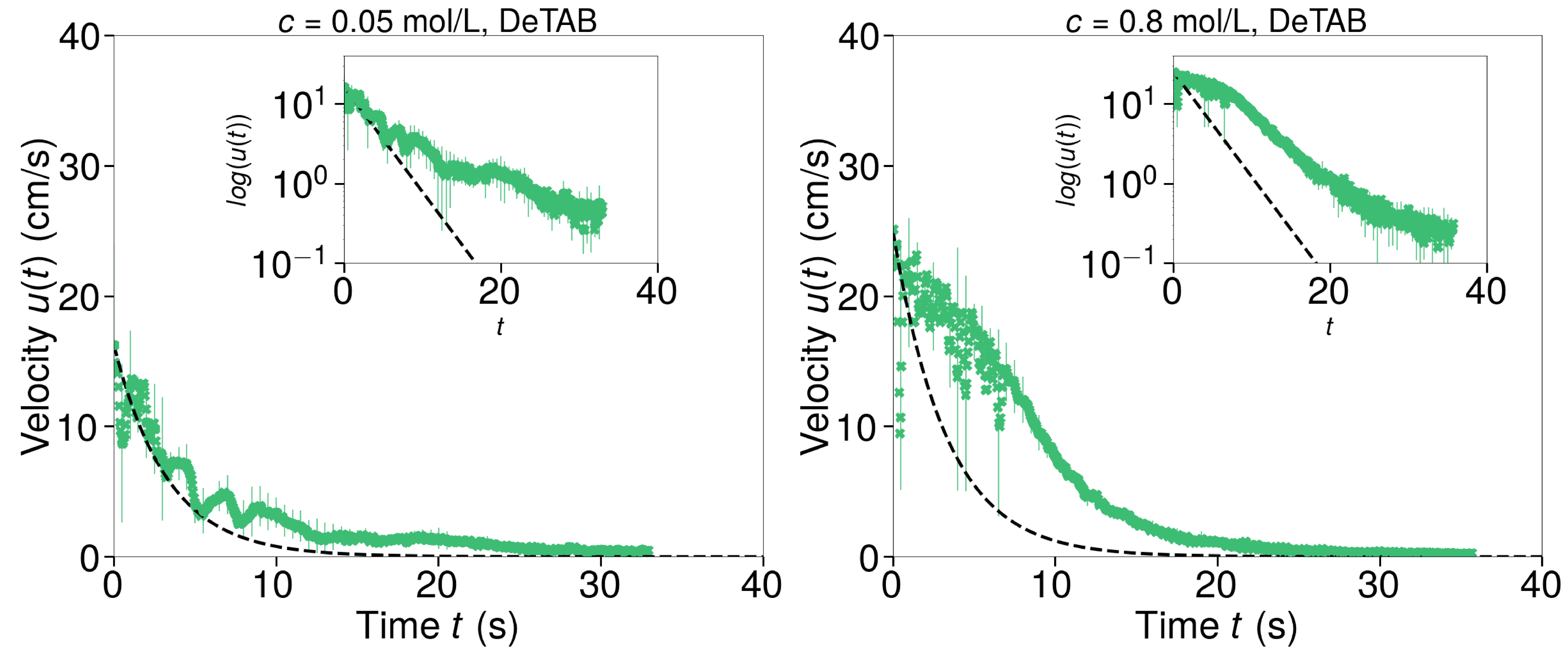
4. Experimental parameters and naive model

- u the velocity, L characteristic length, ν cinematic viscosity, η dynamic viscosity, γ the surface tension.
- Reynolds number:

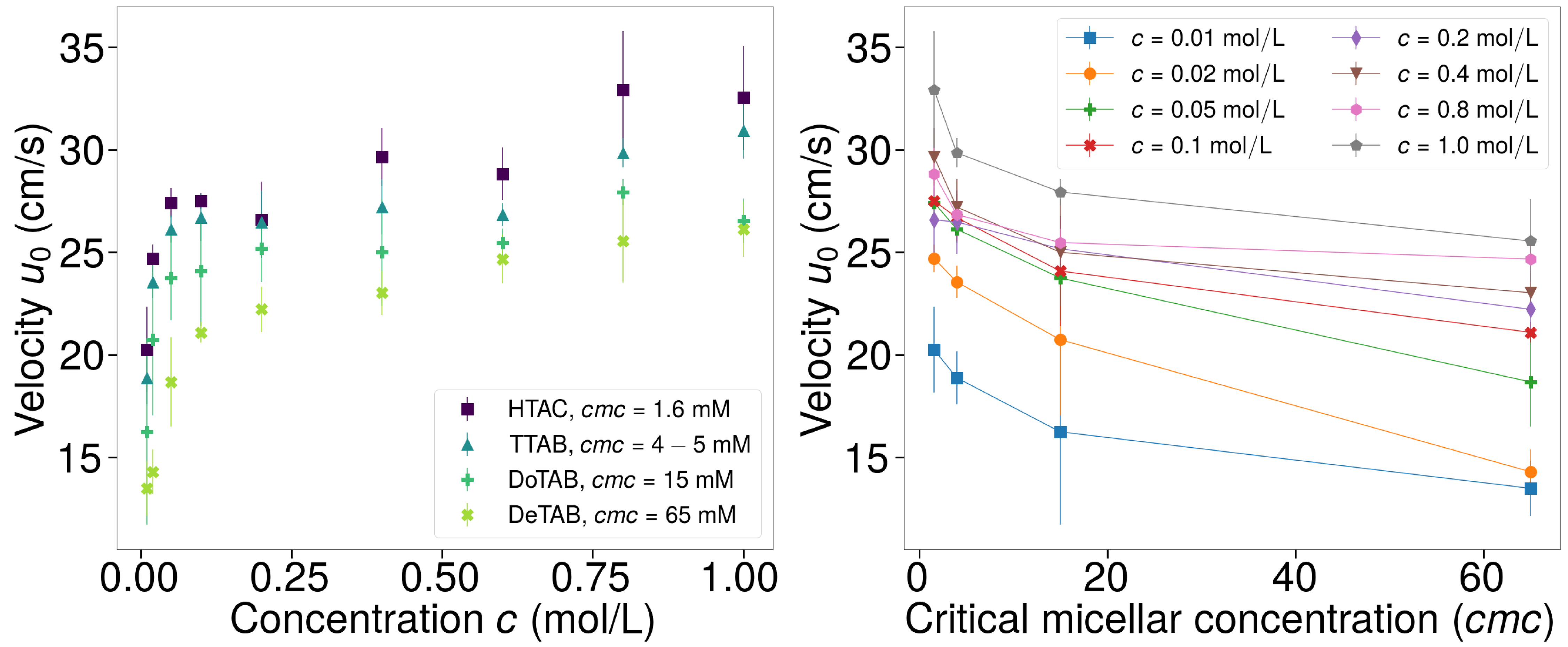
$$Re = \frac{u_0 L}{\nu} = 5000;$$

- Inertial model : $\frac{d\vec{u}}{dt} = -L\eta u$ then $u = u_0 \exp\left(-\mathrm{t}/\tau\right)$ with $\tau = \frac{\mathrm{m}}{\mathrm{L}\eta}$;
- Equation describing the motion of the Marangoni boat:

5. Experimental results



Evolution of the boat velocity with respect to time t for different concencentrations



Measurements of the initial velocity of the boat with respect to the concentration of surfactant (left) and critical micellar concentration (right).

6. Conclusion:

- An inertial model isn't enough to describe the velocity evolution with respect to time of the Marangoni boat;
- In the measurements of the initial velocity with respect to the concentration, two regimes appear. One at low concentration where velocity increases quickly with the concentration and one at high concentration where the velocity increases slowly. This difference is probably due to the Marangoni effect.

7. Future work:

Find a model to predict the velocity and the characterisitic time which takes in account the variation of the $\Delta\gamma$ which is a challenging task [4].