Supplementary Information for manuscript "Depletion attraction impairs the plasticity of emulsions flowing in a constriction"

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ESTIMATION OF THE DEPLETION FORCES RATIO

The depletion force is linear with the concentration of micelles present in the continuous phase [1]. However, the number of micelles is not necessarily linear with the concentration. Indeed, the number of surfactant molecules in one micelle, given by the aggregation number, can grow with the concentration. For SDS, this number has been reported by various authors and yields different values. We calculated the number of micelles for the aggregation numbers reported in three different publications [2]–[4]. Since the depletion force depends on this number, the ratio of forces at 10 and 45mM SDS will be given by the ratio of these numbers R_m.

Thus, based on [2] the aggregation numbers at 10 and 45mM SDS are $N_{10} \sim 38$ and $N_{45} \sim 54$ respectively, based on [3] they are $N_{10} \sim 60$ and $N_{45} \sim 70$ and based on [4] they yield $N_{10} = N_{45} \sim 62$. These numbers in turn lead to ratios in the number of micelles R_m of 25 [2], 30 [3] and 36 [4], which is why we estimate the depletion force to be about 30 times larger at 45mM SDS than at 10mM SDS.

[1] S. Asakura and F. Oosawa, "Interaction between particles suspended in solutions of macromolecules," J. Polym. Sci., vol. 33, no. 126, pp. 183–192, Dec. 1958.

[2] Barney L. Bales, Luis Messina, and Arwen Vidal, M. Peric, and O. R. Nascimento, "Precision Relative Aggregation Number Determinations of SDS Micelles Using a Spin Probe. A Model of Micelle Surface Hydration," 1998.

[3] B. Hammouda, "Temperature Effect on the Nanostructure of SDS Micelles in Water," J. Res. Natl. Inst. Stand. Technol., vol. 118, p. 151, Apr. 2013.

[4] G. Dupltre, M. F. F. Marques, and M. da G. Miguel, "Size of Sodium Dodecyl Sulfate Micelles in Aqueous Solutions as Studied by Positron Annihilation Lifetime Spectroscopy," 1996.

ANALYSIS OF STATIC PACKINGS

As in the deformable particles model (DP model), we fit our data to the following scaling function:

$$\phi_l = \phi_c + \alpha(\mathcal{A} - 1)^{\omega} \tag{1}$$

In particular, we fit the data for polydisperse emulsions prepared with 10mM SDS with the equation $\phi_l = \alpha(\mathcal{A} - 1)^{1/3} + \phi_c$ with a fixed $\phi_c = 0.842$ as numerically computed in the DP model. We find a good agreement between theory and experiments with a prefactor $\alpha = 0.26$. Conversely, when we only fix the prefactor $\alpha = 0.26$, and keep both ω and ϕ_c as free fitting parameters, we recover $\omega = 0.36 \pm 0.1$ and $\phi_c = 0.848 \pm 0.02$, which are also very close to the numerically computed ones.

We perform the same fitting procedure for the 45mM SDS emulsion data. For fixed ω and ϕ_c we recover a prefactor $\alpha = 0.28$, that in turn leads to $\omega = 0.37 \pm 0.08$ and $\phi_c = 0.85 \pm 0.013$. As shown in Figure 1, both SDS concentrations cannot be distinguished and both agree with the same fit function. A summary table of all performed fits for both conditions is given in Table I.

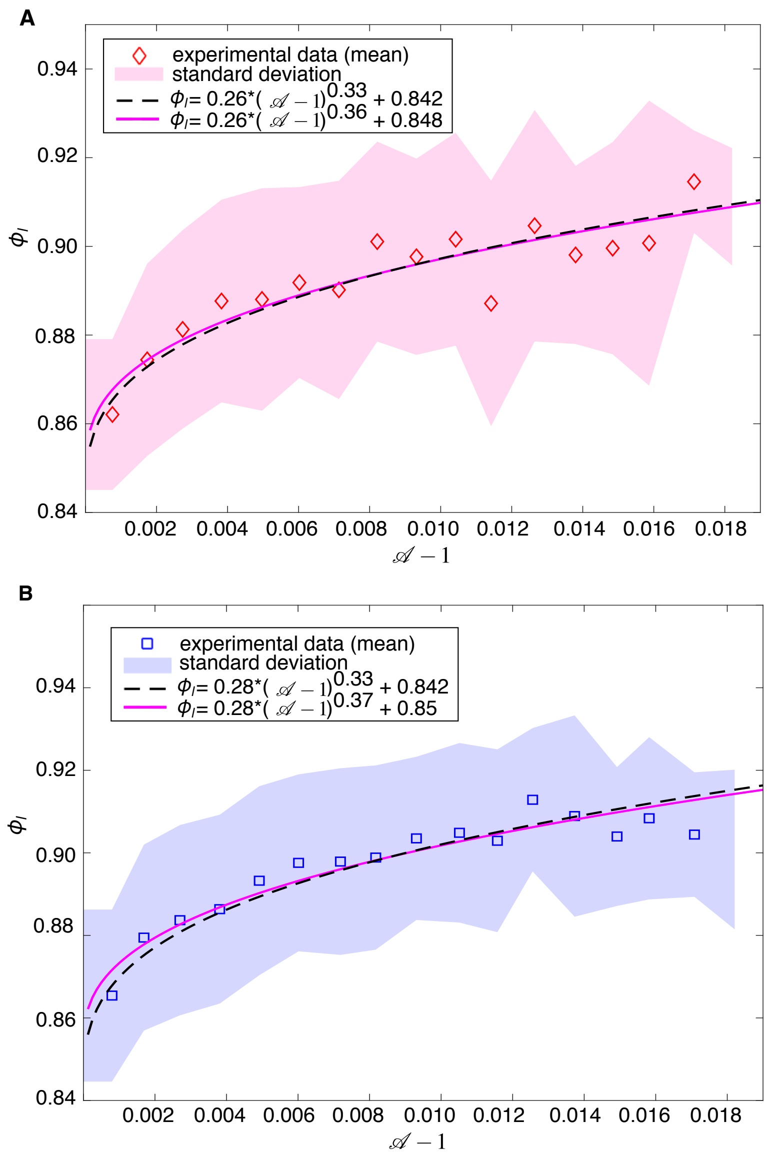

FIG. 1. Local packing fraction ϕ_l versus $\mathcal{A} - 1$ for 10mM (A) and 45mM SDS (B) emulsions. The experimental points (red open diamonds for 10mM SDS in A, blue open squares for 45mM SDS in B) are plotted together with the DP model with the exponent fixed to 1/3 and $\phi_c = 0.842$ (black dashed line). The pink dashed line is the best power law fit with the prefactor fixed.

[SDS]	Fixed parameters	Free parameters
10mM	$\omega = 0.33$ $\phi_c = 0.842$	$\alpha = 0.26$
	$\alpha = 0.26$	$\omega = 0.36 \pm 0.1$ $\phi_c = 0.848 \pm 0.02$
	$\omega = 0.33$	$\alpha = 0.23 \pm 0.06$ $\phi_c = 0.846 \pm 0.012$
	$\phi_c = 0.842$	$\omega = 0.29 \pm 0.09$ $\alpha = 0.21 \pm 0.09$
45mM	$\omega = 0.33$ $\phi_c = 0.842$	$\alpha = 0.28$
	$\alpha = 0.28$	$\omega = 0.37 \pm 0.08$ $\phi_c = 0.85 \pm 0.013$
	$\omega = 0.33$	$\alpha = 0.24 \pm 0.05$ $\phi_c = 0.849 \pm 0.01$
	$\phi_c = 0.842$	$\omega = 0.28 \pm 0.06$ $\alpha = 0.21 \pm 0.06$

TABLE I. List of all fitting parameters obtained for various fixed parameters applied to the deformable particle model equation.

INFLUENCE OF FLOW SPEED ON DROPLET DEFORMATION IN THE CHANNEL

The droplets are individually tracked in the channel in order to extract their average velocity. For a given velocity we measure the average deformation of all considered droplets. We thus check that the deformation does not depend on the imposed flow for both SDS concentrations.

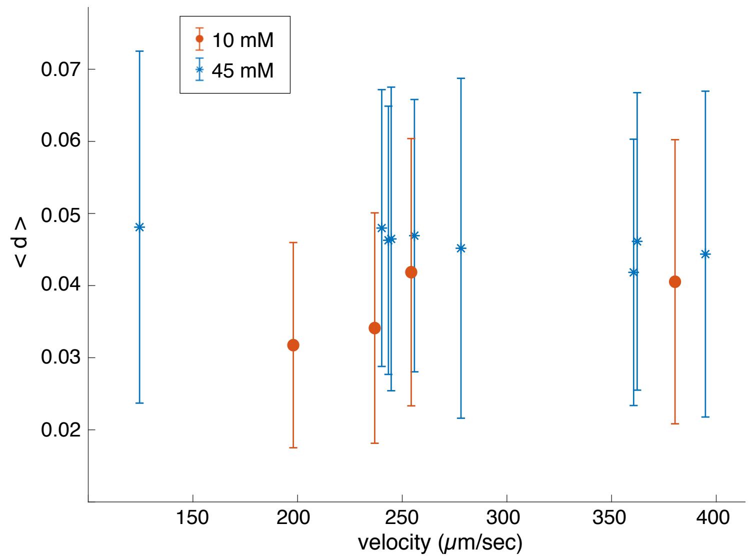

FIG. 2. Average deformation $\langle d \rangle$ as a function of droplet velocity in the small channel.

INFLUENCE OF FLOW SPEED ON THE LOCATION OF VELOCITY MINIMUM IN THE CONSTRICTION

We studied the effect of the flow speed on the location of velocity minima in the specific areas in the constriction (Zone 1 and Zone 2). We compare the cumulative distributions of these locations for all the experiments and for the experiments with the same flow speed (71μm/s in the wide channel ahead of the constriction) for 10mM and 45mM emulsions respectively. One can see that the flow rate does not affect the distributions.

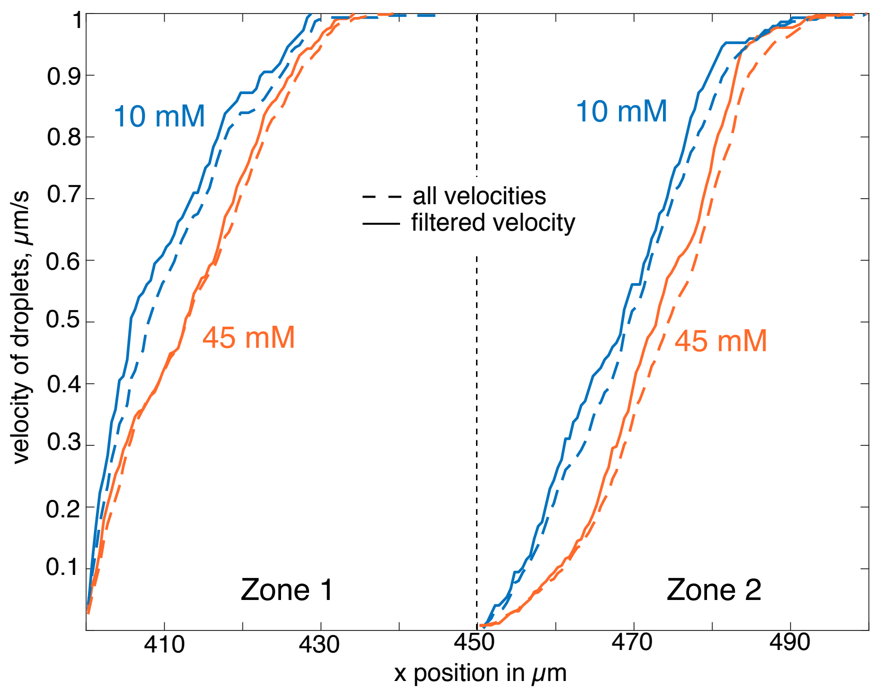

FIG. 3. Cumulative distributions of the minimum velocity location as a function of flow speed in the wide channel. The minima are found for the droplets in lines 1 and 4 for 10mM (blue) and 45mM (orange) SDS, in zones 1 and 2. Dashed lines are obtained for all velocities (average velocity of $76 \pm 10\mu$m/s for 10mM SDS and $97 \pm 13\mu$m/s for 45mM SDS), solid lines are obtained for data that is filtered as a function of droplet velocity, in particular we only keep droplets displaying a similar average velocity of $71 \pm 3\mu$m/s.

Supplementary movie: Typical movie of an emulsion flowing in the microfluidic constriction. The emulsion is here stabilized with 10mM SDS.