Research Log November 19, 2021

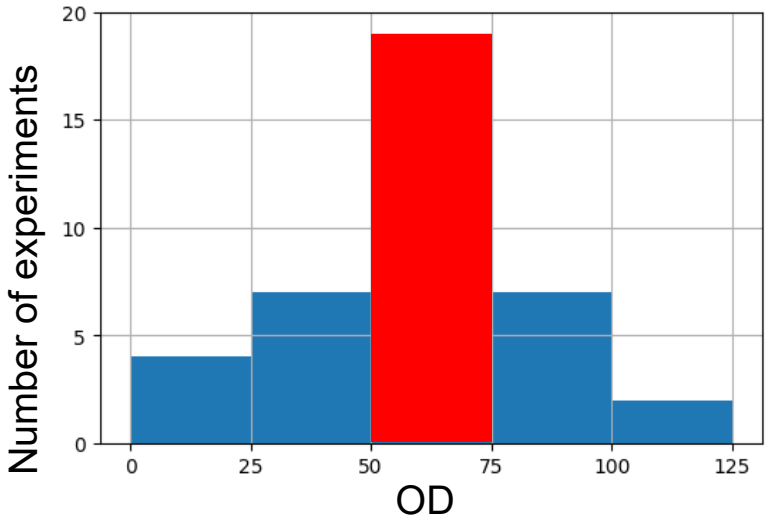
We summarize the inner droplet motion data and get more data from tracking 2 um PS particles in bacterial droplets.

Results

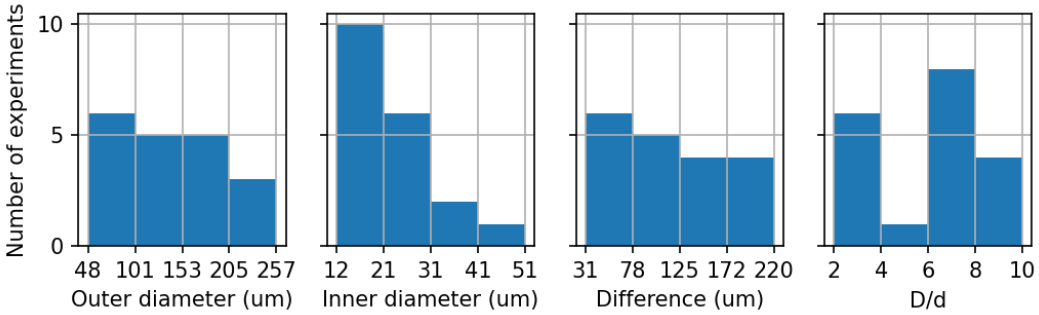
1. Inner droplets of double emulsions (hand tracking at 1 frame per second)

Experiments are performed at various outer diameters (D), inner diameters (d) and bacterial concentrations (OD). Among the three parameters, we have the best control over OD since we can do dilution during the bacterial sample preparation. Therefore, the preliminary experiments, **we keep OD roughly constant and study the effects of geometry (outer and inner droplet sizes).**

The OD distribution of our experiments is shown below:

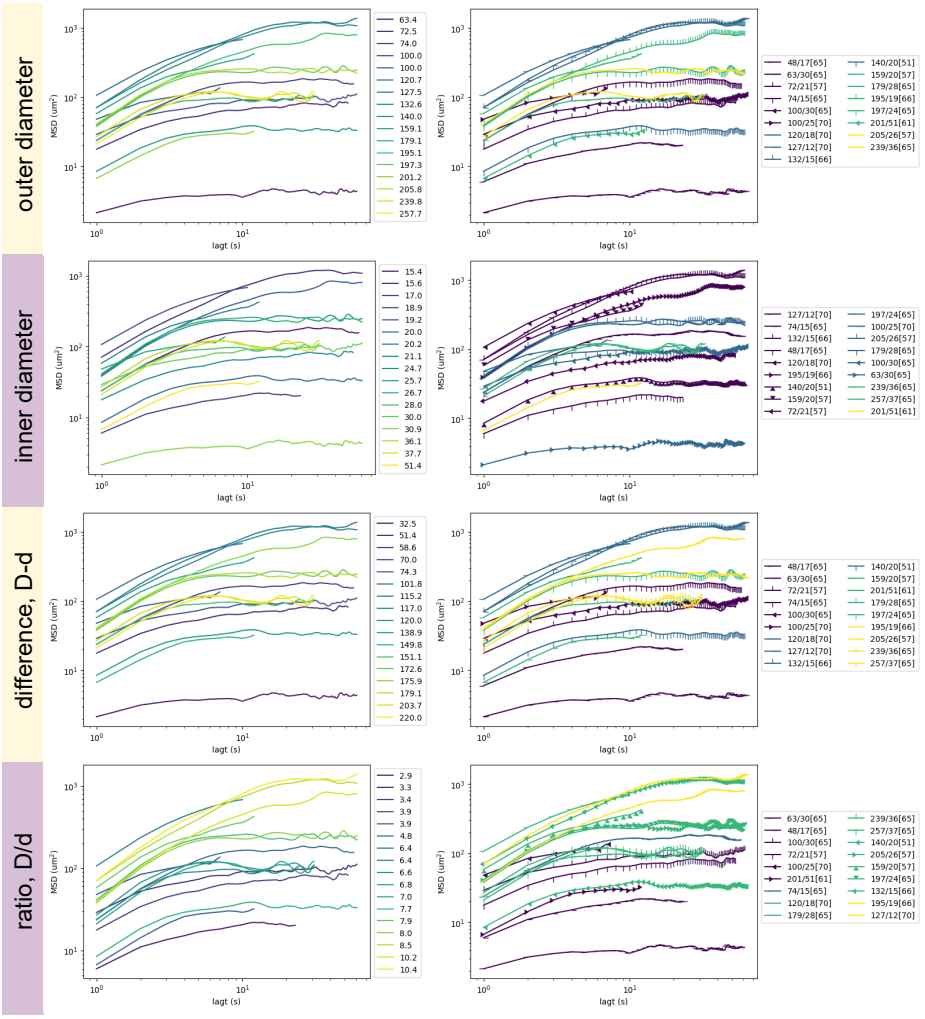


We have 19 runs within the OD range (50, 75). The size distribution of these 19 runs is shown below:

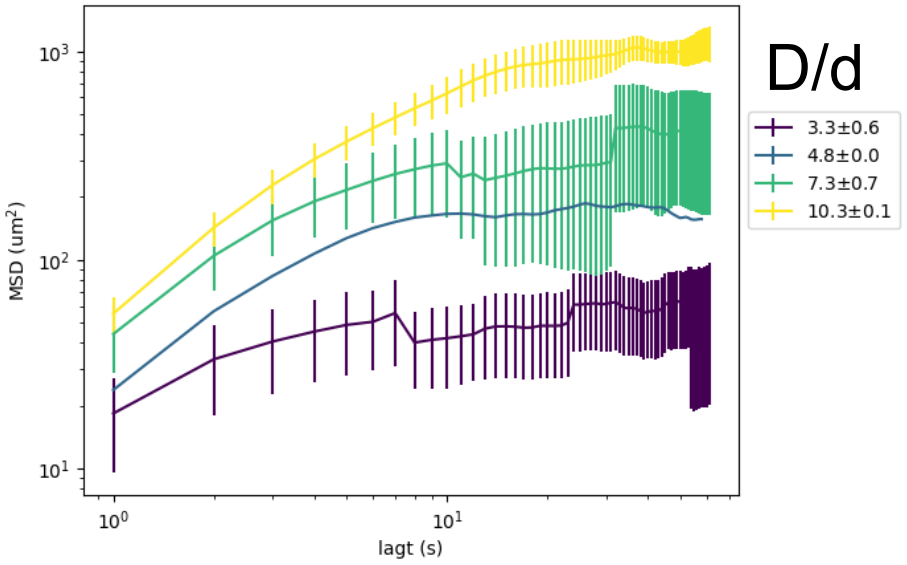


We have multiple runs for almost all the brackets of different size parameters. Let's compare the diffusivity, see which parameter groups the diffusion curves best. **Intuitively, large outer droplet + small inner droplet together give rise to high diffusivity. That is, a larger difference (D-d) or ratio (D/d) would correspond to higher MSD curve.**

The MSD curves are summarized in the following figure, by grouping the curves by outer diameter, inner diameter, difference and ratio.



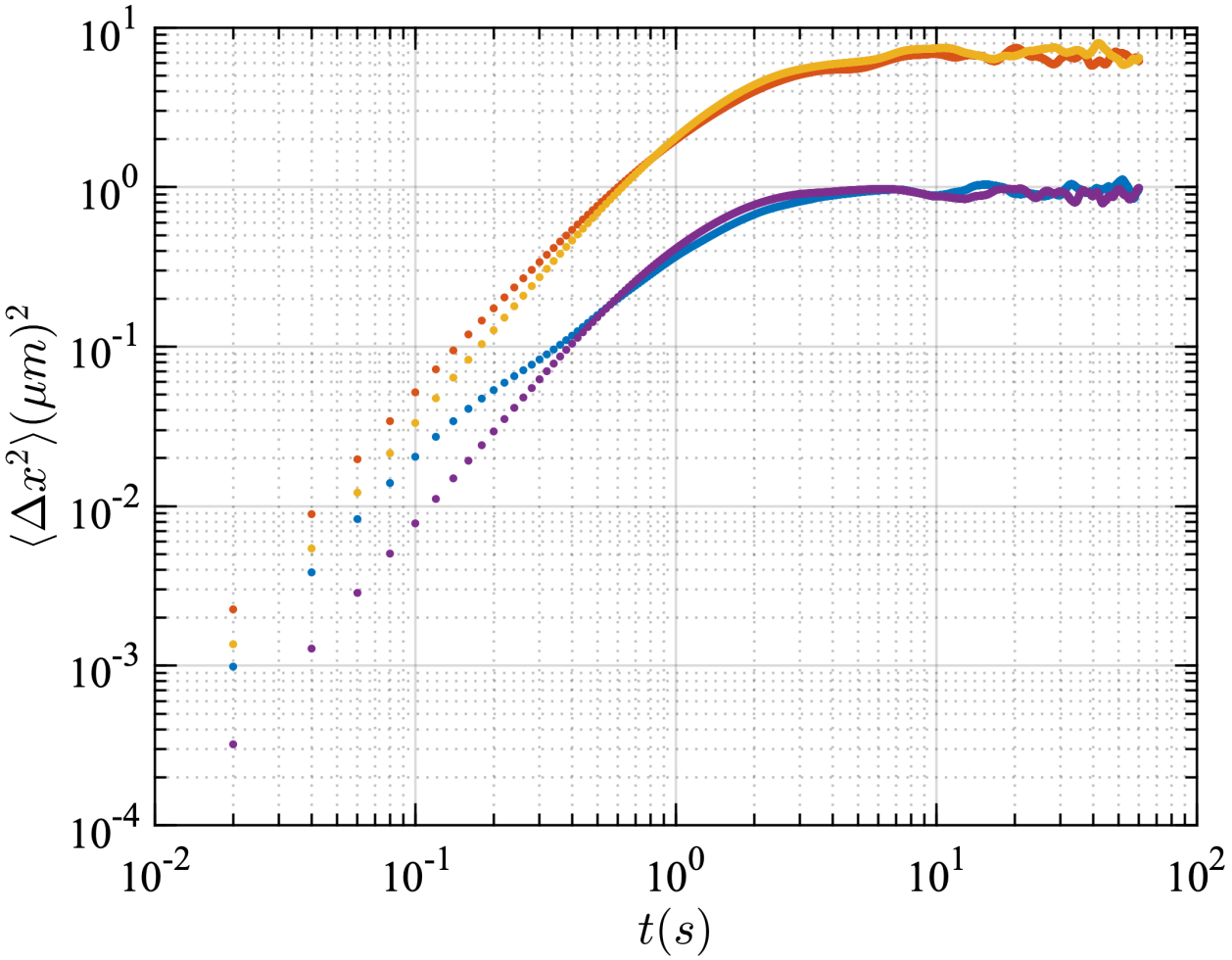
Indeed, for the regrouping based on size ratios (D/d), we see a monotonic increasing of the magnitude of MSD curve with D/d. If we average the runs within each group, the plot gets cleaner:

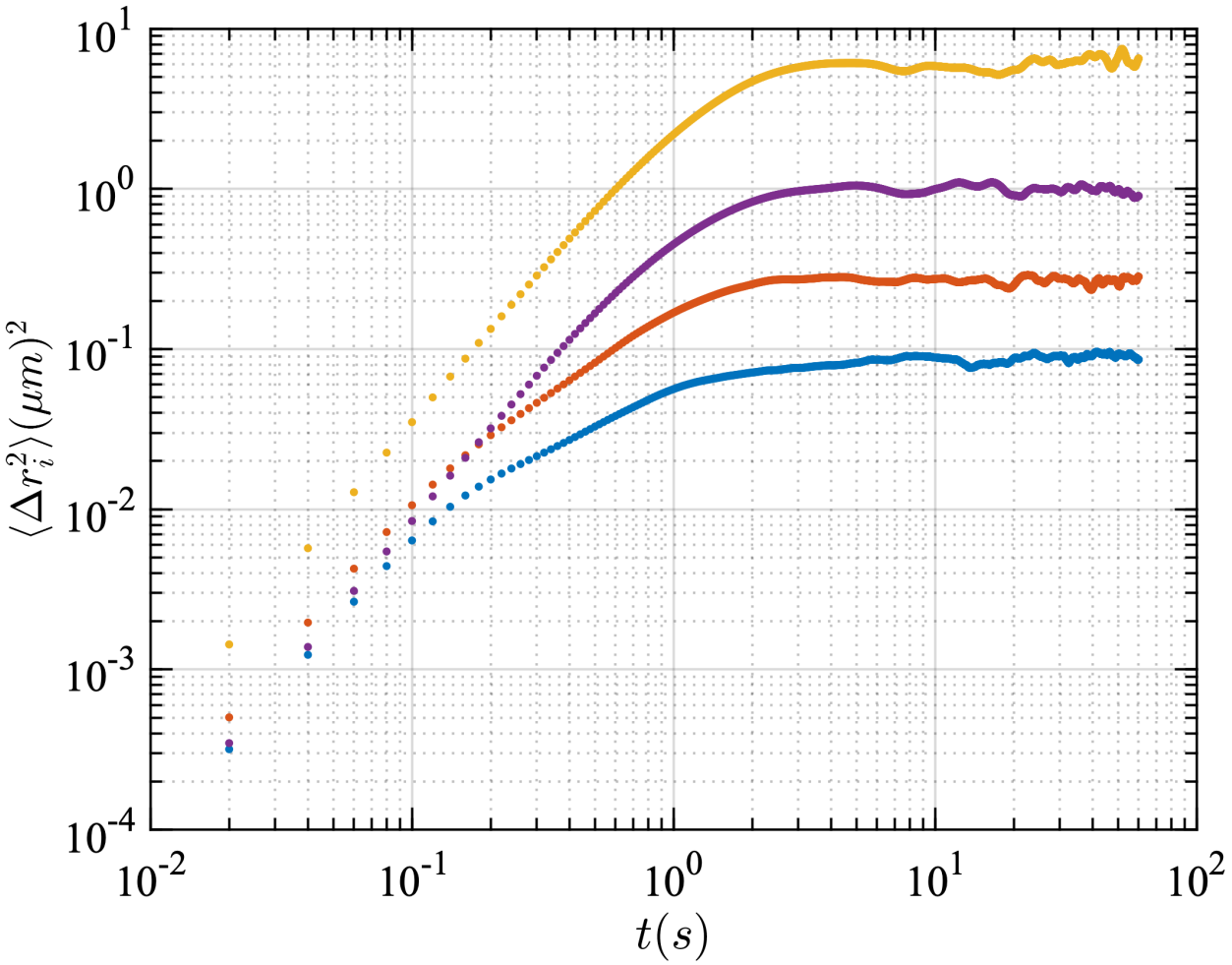


The trend of the MSD magnitude (wrt size ratio D/d) is consistent with our intuition. More information can be extracted from the motion of the inner droplets: **the time scale where transitions from ballistic to diffusive to confined motion happens (2→1→0).** However, these information requires a more time resolved trajectory, which is beyond the capability of manual tracking. A model which captures these transitions in MSD is also needed, so we have a systematic way to fit the data, and understand the origin of the phenomena.

1.1 Double Emulsion experiments full tracking

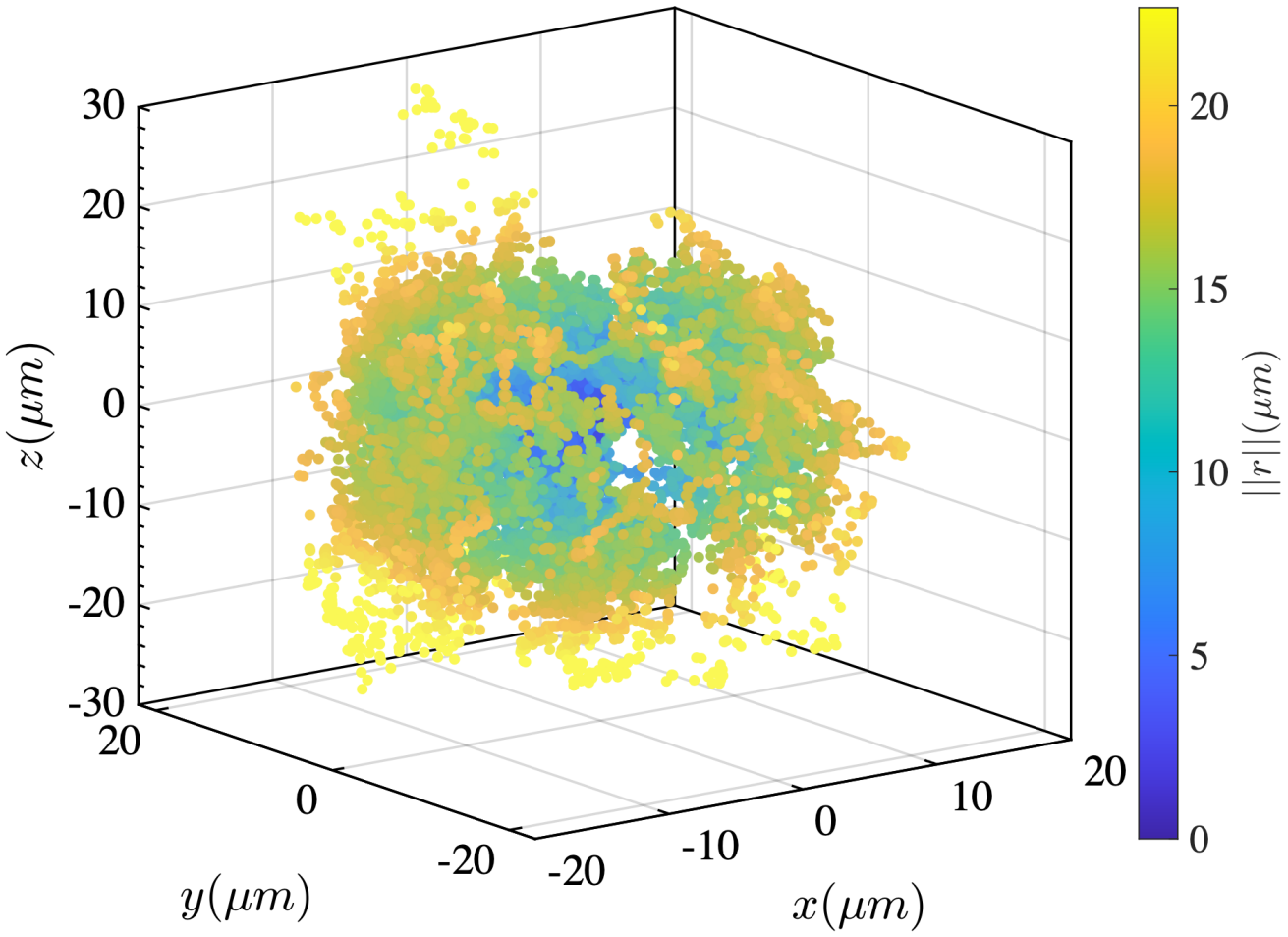
Same saturation value.





2. 2-um particle motion in bacterial droplets.

We change the particles to see if we can increase the precision of the tracking system. The first control experiment was compare the Brownian motion of the particles in the bulk of a pool, since this phenomena do not have any persistence is the hardest case for the tracking system.



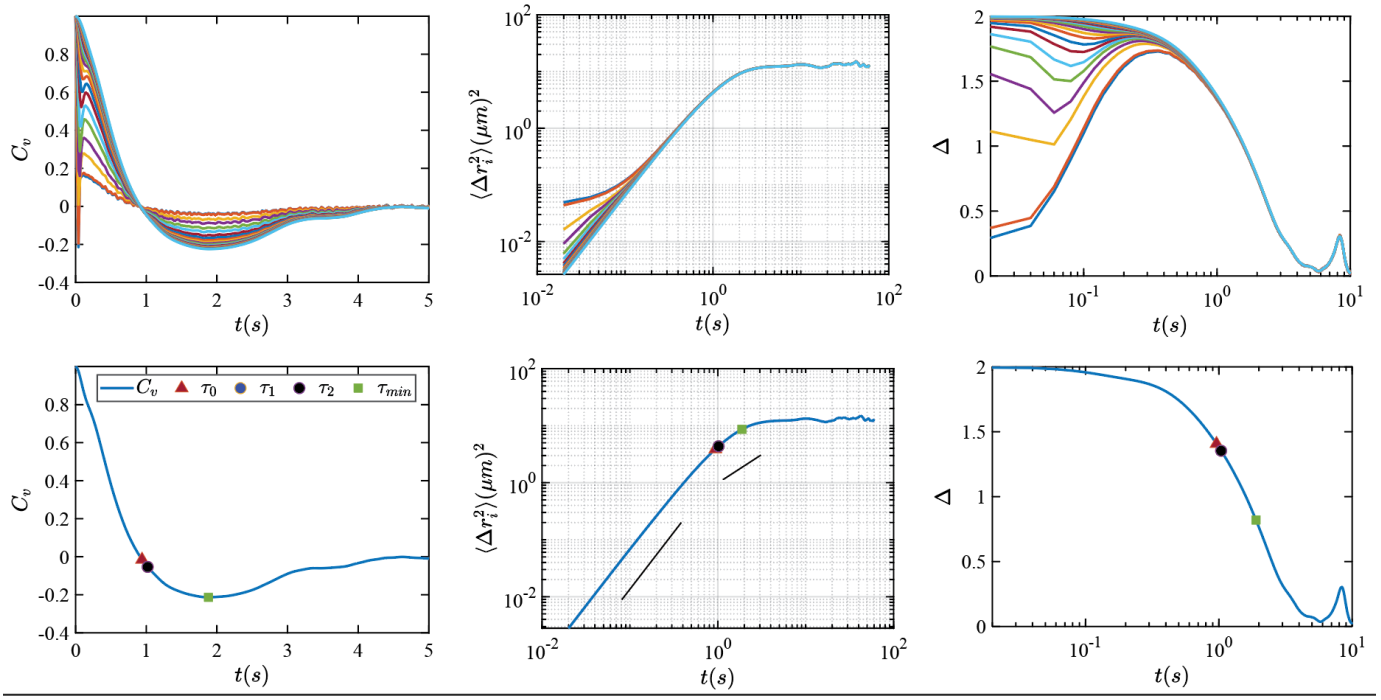
3. Window size analysis.

In order to find the best window size to smooth the data and have a more representative measure of the velocity, we vary the size of the window size and compute different time scales from the velocity autocorrelation function.

We compare two smoothing methods from MATLAB.

1. Gaussian smoothing which smooth the data within a window using a Gaussian distribution.
2. Savitzky-Golay which use a polyfit (order 2 by default) of a specific order to smooth the data in some window size.

For the experiments of Double emulsion the primary source of artificial noise is the tracking algorithm, since we find circles within a certain radius the position of the center will vary due to the change of the radii and the center accuracy to find the inner droplet. So after making the tracking of both droplets (outer and inner) the coordinates will be always taking from the center of the outer droplet.



For example in the figure we vary the window size from 0.02 to 0.4 (s). As we know the MSD and the velocity autocorrelation function are sensitive to the smoothing process. We can see that at short windows size the Vacf present a negative peak close to $t = 0$, and the MSD is sub diffusive. We know that the MSD should be ballistic at short times, and the diffusive regime is short or there's no diffusive regime. From the MSD and VACF we want to find some characteristic time scale. For example for a passive tracer in a dilute bacterial bath has been shown that the persistent length goes as $l = \tau v_0$, where τ is the correlation time of the velocity of the probe and is extracted from the VACF as a fit $e^{-t/\tau}$, and v_0 is the velocity at short times, that can be computed as the limit of the MSD at short times $MSD \propto v_0^2 t^2$. But the system of the double emulsion is different because of the confinement and from previous approximated result we know that the MSD and VACF will be modeled as two exponential, so there will be more than one characteristic time scale, and therefore will be sensitive to the smoothing process. We define two characteristic times τ_0 and τ_{min}, as the the time to reach zero and the time to reach the minimum value of the VACF respectively. And we fit the velocity autocorrelation function with the following function $\hat{C}_v(t) = \frac{t_2 e^{-x/t1} - t_1 e^{-x/t_2}}{t_2 - t_1}$ to extract τ_1 and τ_2.

4. Prototype of the W/O/W double emulsion experiment

A list of videos

Videos are for entertainment. Here is a list.

Particles on the surface of "active droplet"

3D reconstruction of a Z-scan pancake

Large R/r real time video

Small R/r real time video

Rotate microscope, XZ → XY This is how we image the same double emulsion in both XY and XZ planes

Counting bacteria