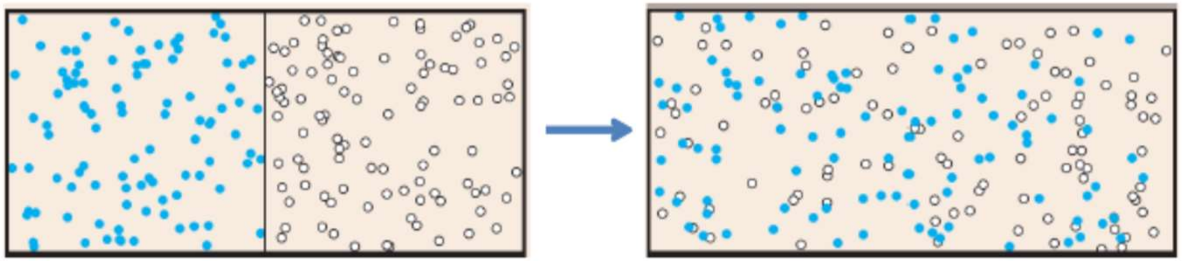
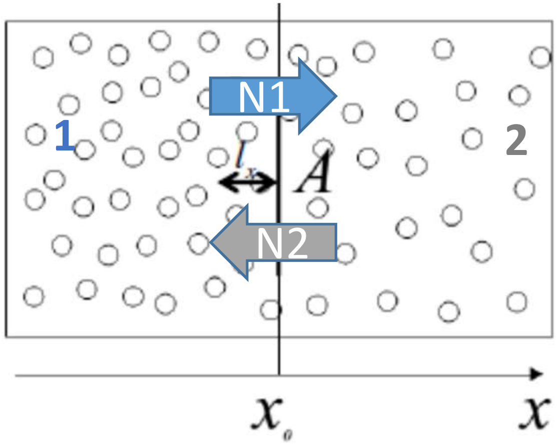
Diffusion

- Random Walk
- Diffusion of potassium permanganate
- Image evaluation

Brownian motion: Random uncorrelated motion of particles due to the thermal motion and random collisions.

Diffusion: A net observable material transport, which lasts until there is an equilibration of the concentration over space
(in thermal equilbrium, and free diffusion)





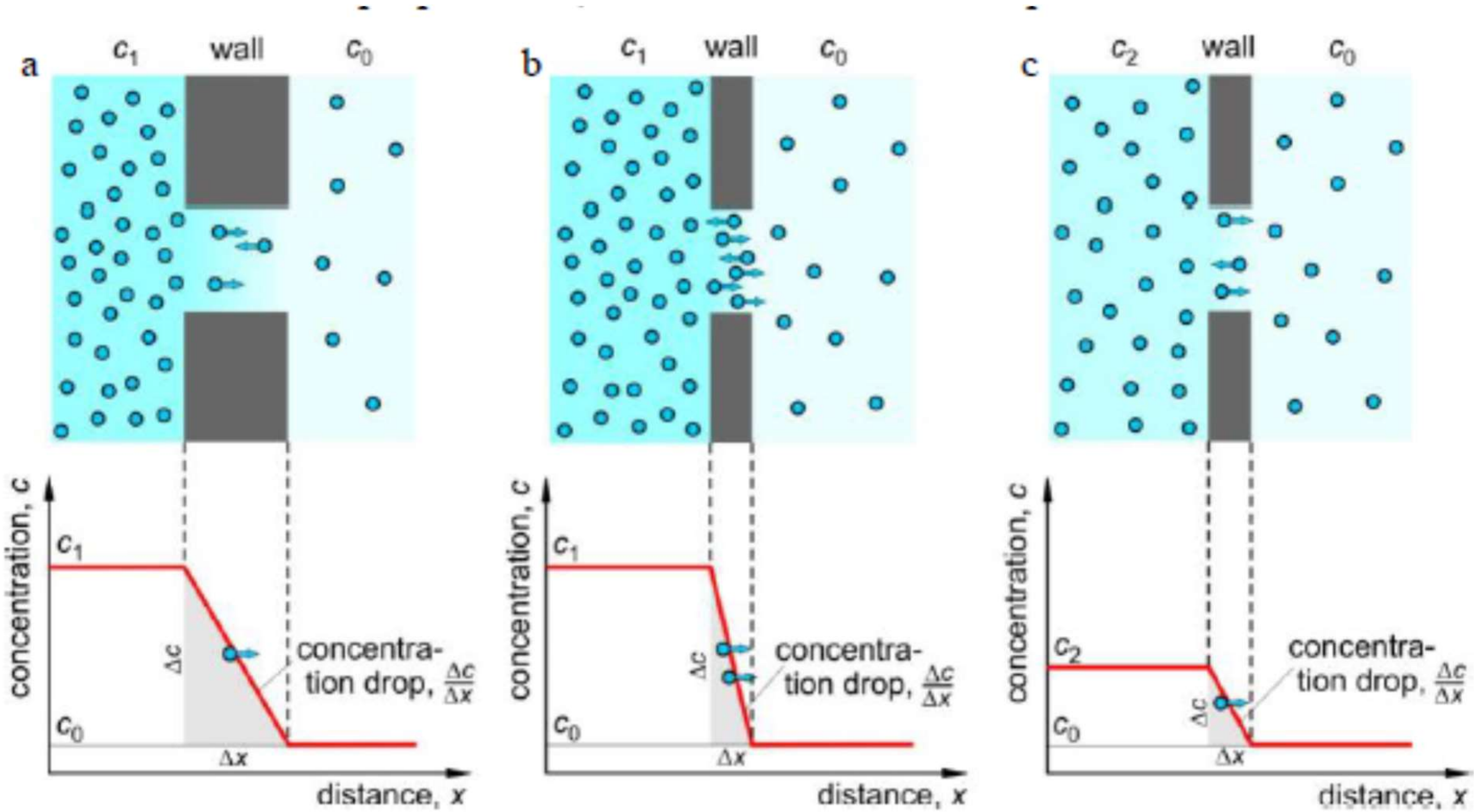
$\Delta N = N1 - N2$

$N1 \sim c_1$; $N2 \sim c_2$

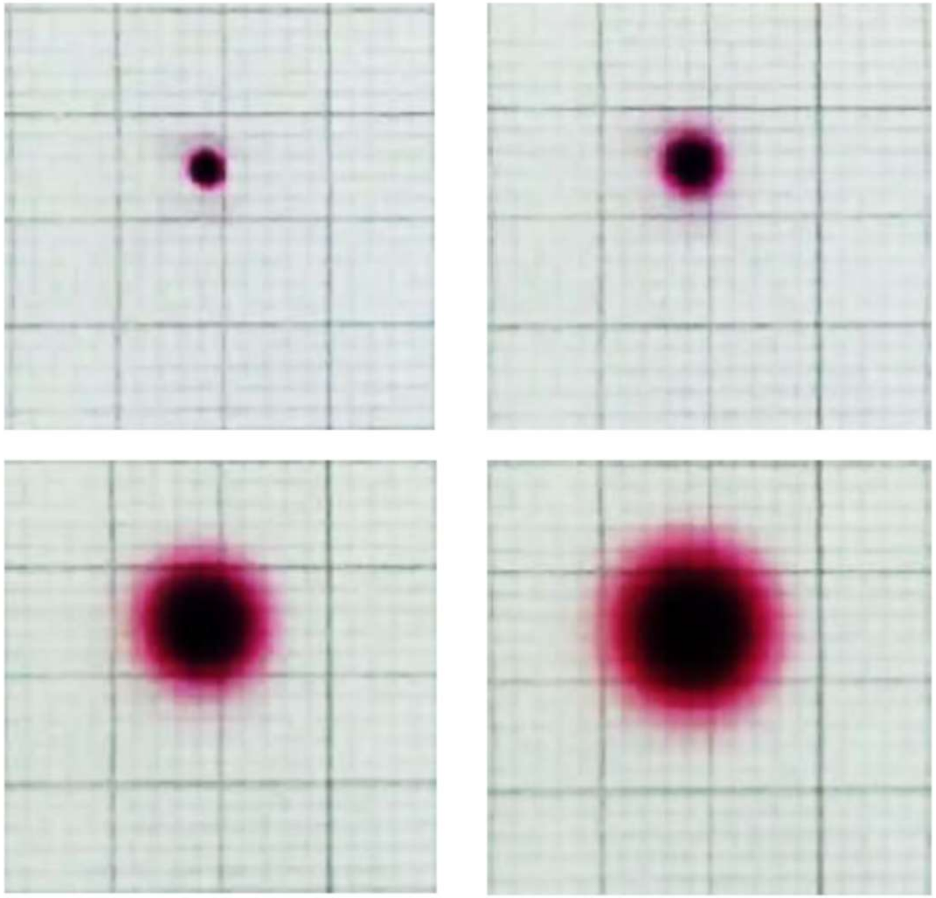
$\Delta V = l * A$; $N = c * \Delta V$

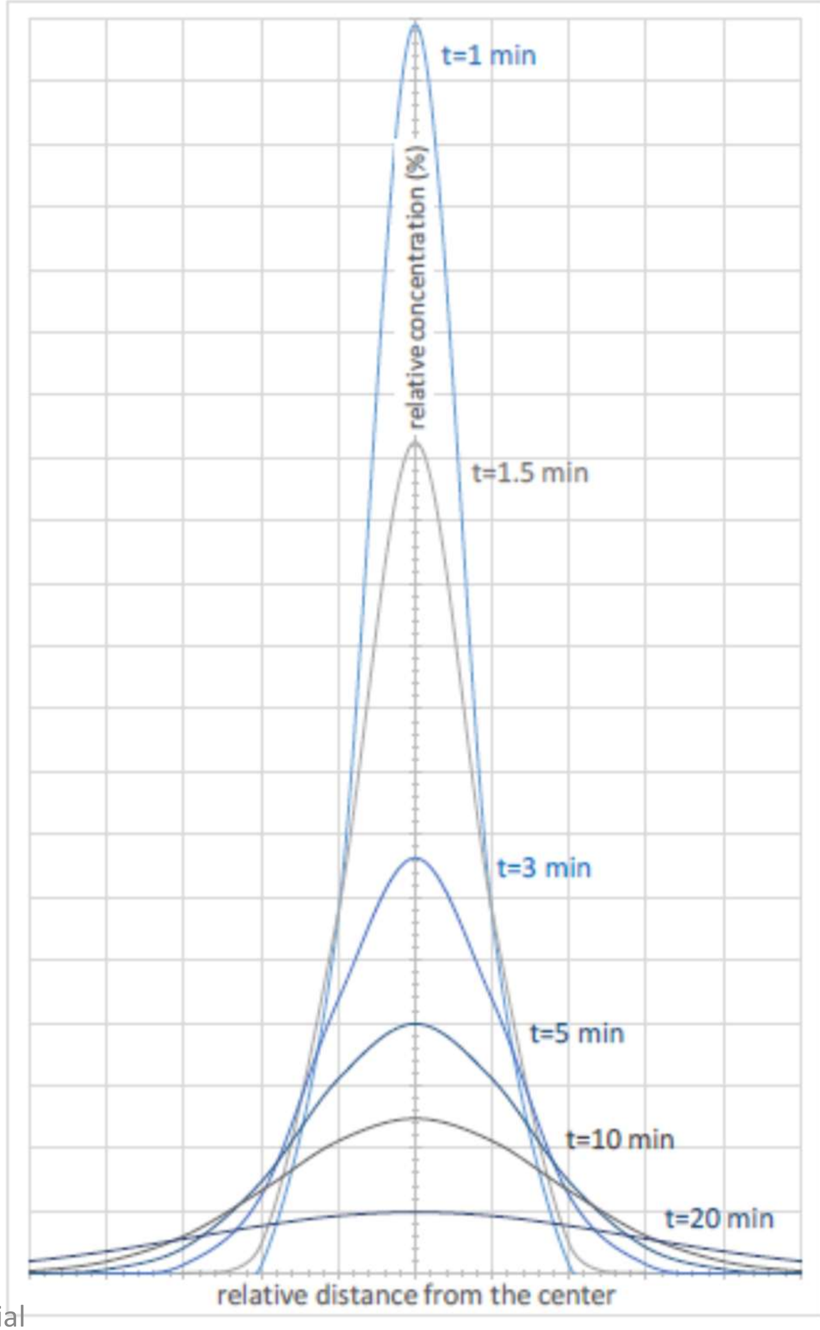
$$J_v = -D \cdot \frac{\Delta c}{\Delta x}$$

$$D \cdot \frac{\Delta \left(\frac{\Delta c}{\Delta x} \right)}{\Delta x} = \frac{\Delta c}{\Delta t}.$$


a
c_1
wall
c_0
concentration, c
c_1
c_0
Δc
Δx
concentra-
tion drop, $\frac{\Delta c}{\Delta x}$
distance, x
b
c_1
wall
c_0
concentration, c
c_1
c_0
Δc
Δx
concentra-
tion drop, $\frac{\Delta c}{\Delta x}$
distance, x
c
c_2
wall
c_0
concentration, c
c_2
c_0
Δc
Δx
concentra-
tion drop, $\frac{\Delta c}{\Delta x}$
distance, x

Potassium permanganate diffusion
from a starting spot over time





$$D \cdot \frac{\Delta\left(\frac{\Delta c}{\Delta x}\right)}{\Delta x} = \frac{\Delta c}{\Delta t}.$$

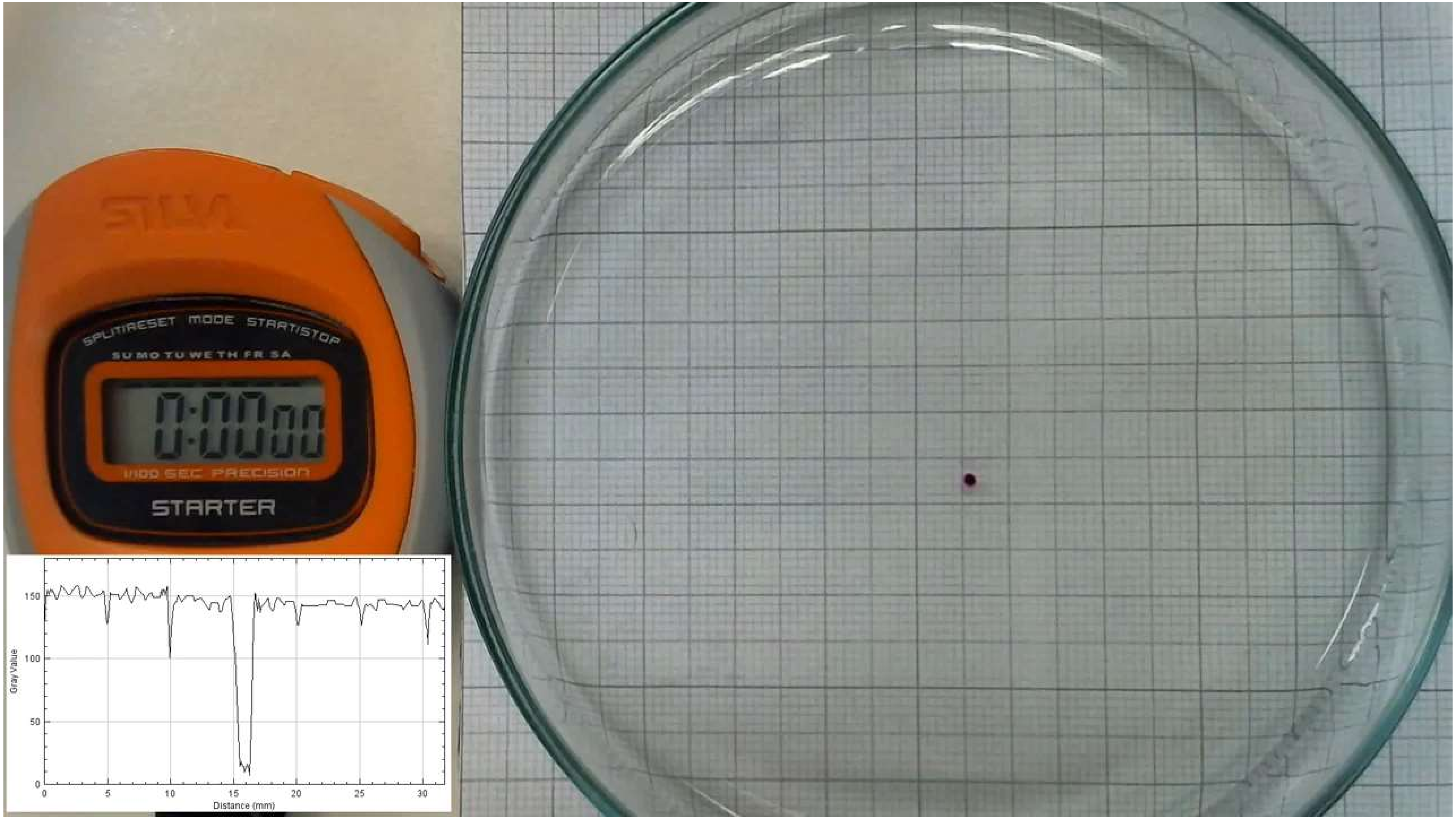
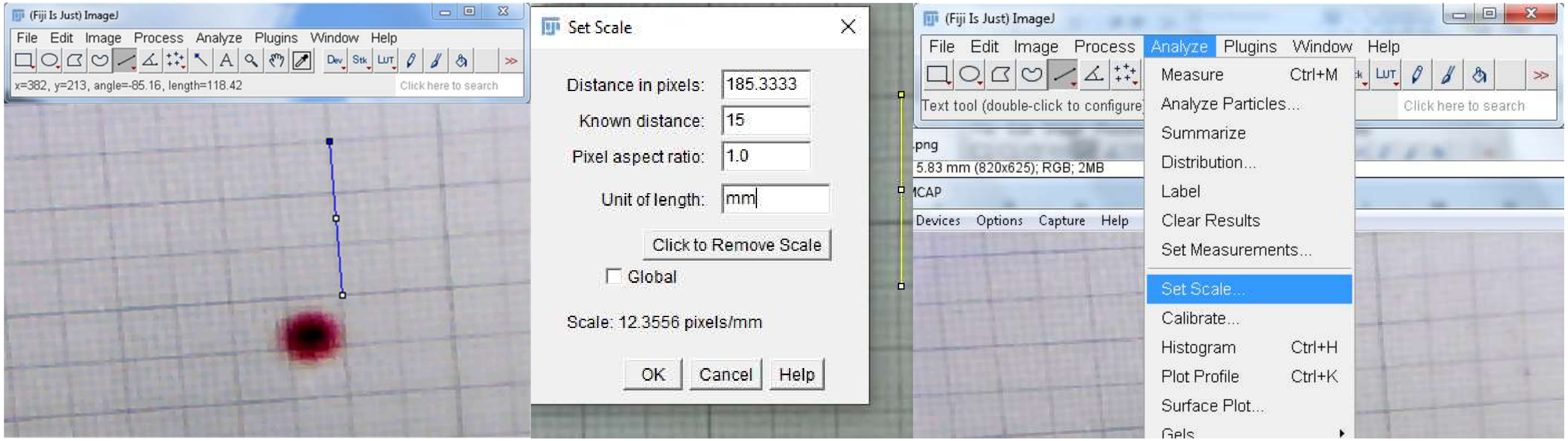
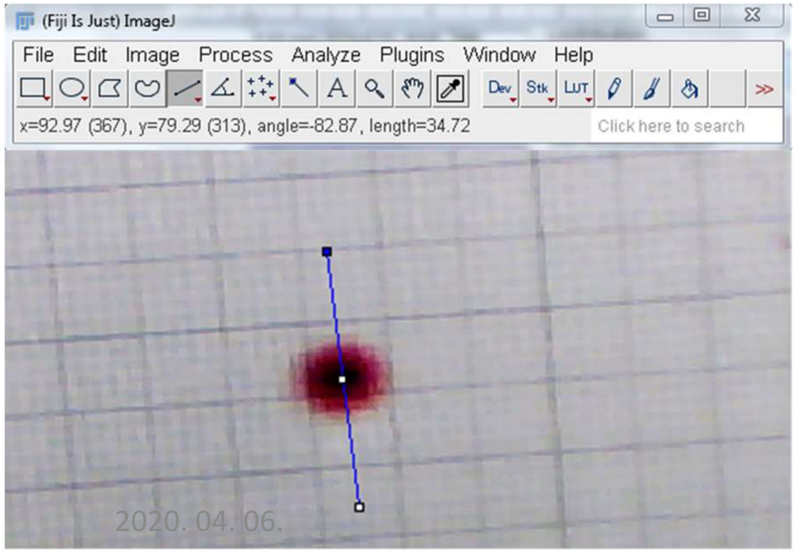

SPLIT/RESET MODE START/STOP
SU MO TU WE TH FR SA
0:00 00
1/100 SEC PRECISION
STARTER
Gray Value
150
100
50
0
0
5
10
15
20
25
30
Distance (mm)

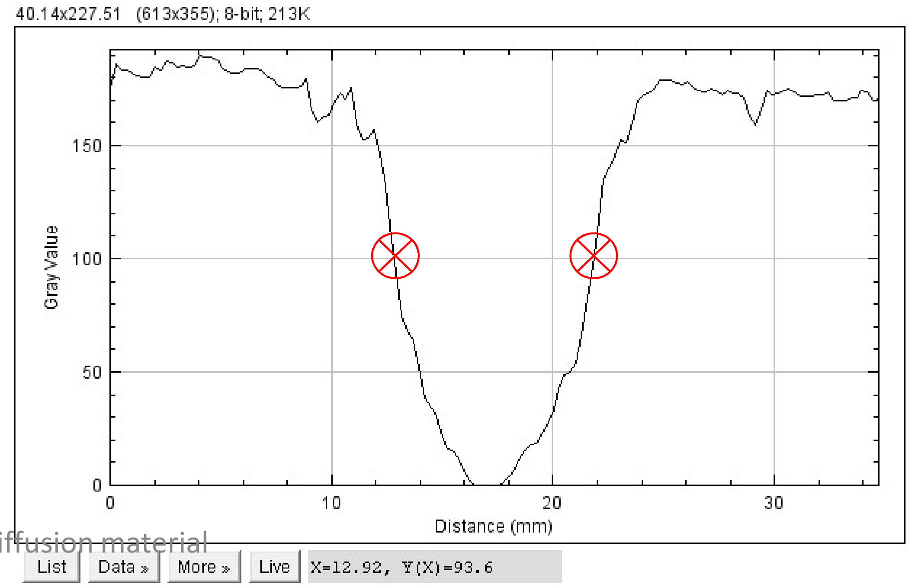
Image analysis:

1. Calibrate the image



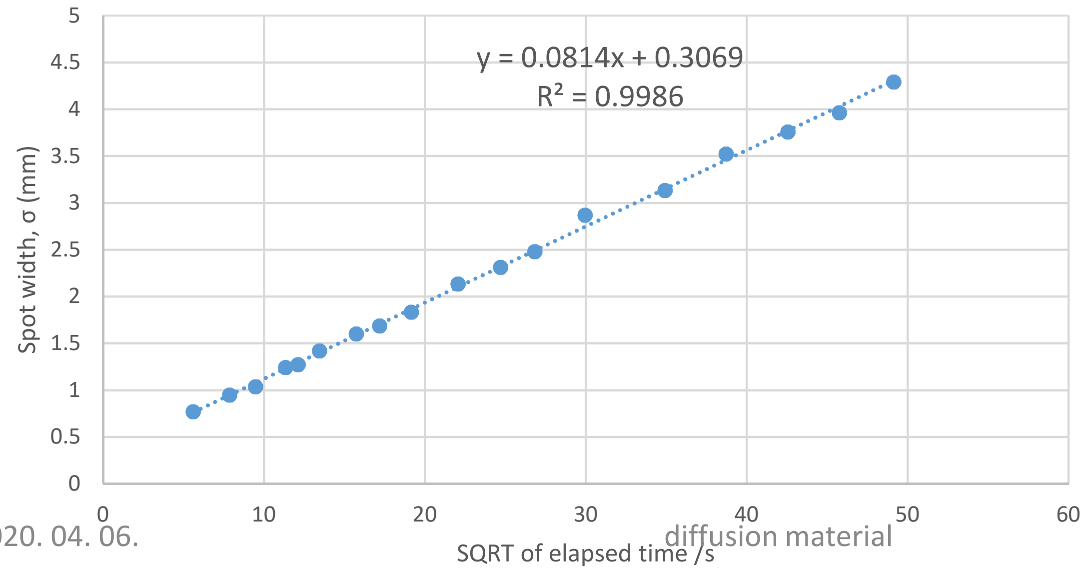
2. Plot the intensity profile





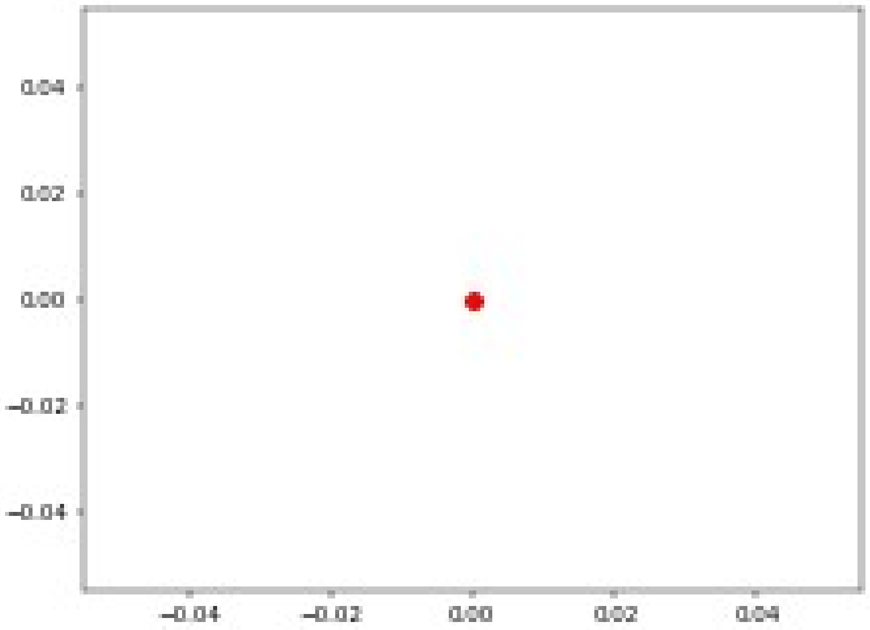
Time (min)	*Real timepoint of the image (s)*	*left side of the spot (mm)*	*right side of the spot (mm)*
0.5	31.5	5.74	7.87
1	62	4.84	7.46
1.5	90	4.26	7.13
2	129	4.84	8.28
2.5	147	4.92	8.44
3	181	8.77	12.7
4	248	7.7	12.13
5	296	8.36	13.03
6	367	7.21	12.29
8	487	7.29	13.2
10	611	6.8	13.2
12	720	4.59	11.46
15	898	4.75	12.7
20	1220	4.43	13.11
25	1500	4.26	14.02
30	1811	8.85	19.26
35	2095	6.48	17.46
40	2415	6.72	18.61

square-root of the time (/s)	*diameter (FWHM) of the spot (mm)*	*width parameter of the bell-shaped curve σ (mm)*
5.61248608	2.13	0.76884856
7.87400787	2.62	0.945719825
9.48683298	2.87	1.035960266
11.3578167	3.44	1.241708472
12.1243557	3.52	1.270585413
13.453624	3.93	1.418579737
15.7480157	4.43	1.599060619
17.2046505	4.67	1.685691443
19.1572441	5.08	1.833685767
22.0680765	5.91	2.133284032
24.7184142	6.4	2.310155297
26.8328157	6.87	2.479807326
29.9666481	7.95	2.869646033
34.9284984	8.68	3.133148121
38.7298335	9.76	3.522986828
42.5558457	10.41	3.757611975
45.77117	10.98	3.963360181
49.1426495	11.89	4.291835387

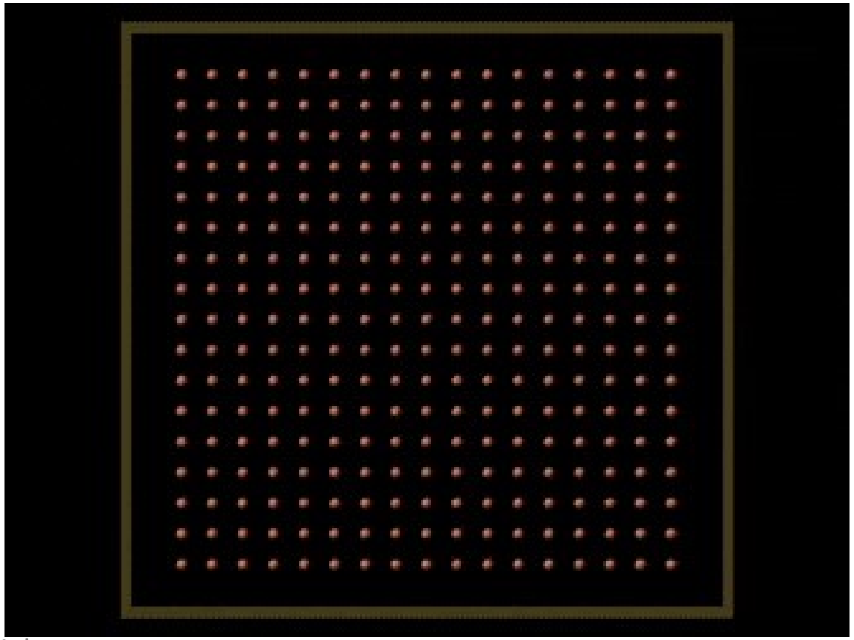


$$D = \text{slope}^2/2$$

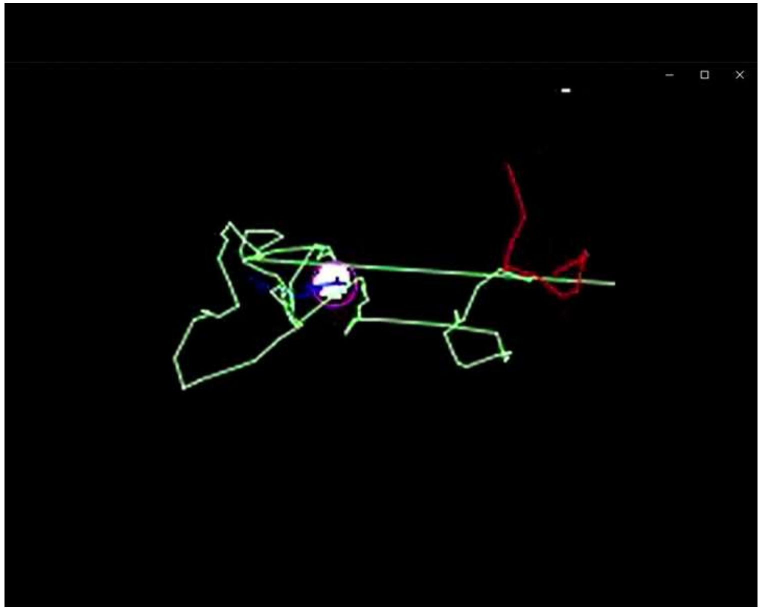
The average distance covered by a particle can be calculated from the random walk model



The particles move randomly uncorrelated.
Each step is in a rendom direction, generating a zig-zag pattern

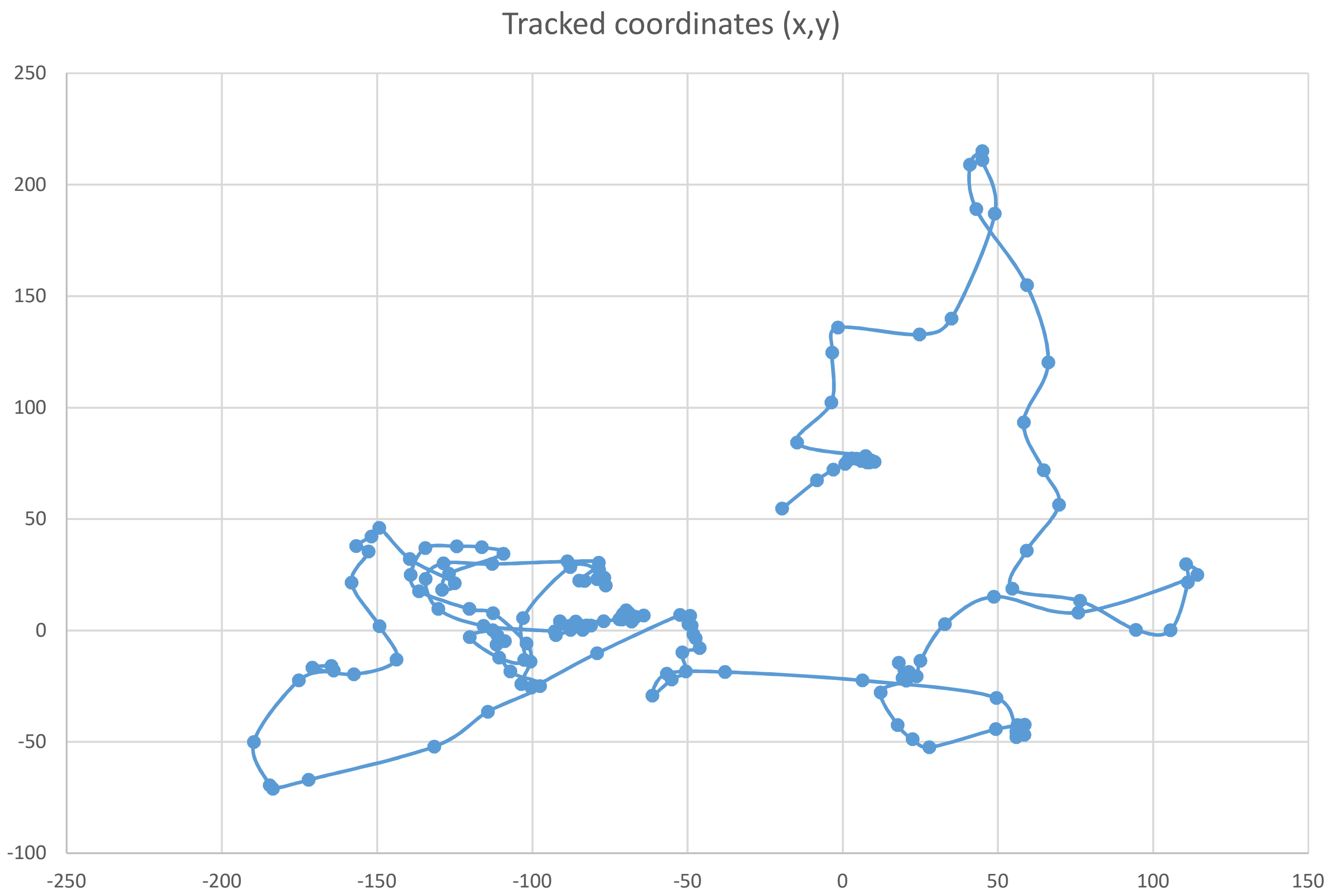


Macroscopic (scaled-up) home made model: the fluidized poppy-seeds act as the solvent. The white foam ball acts as the particle.

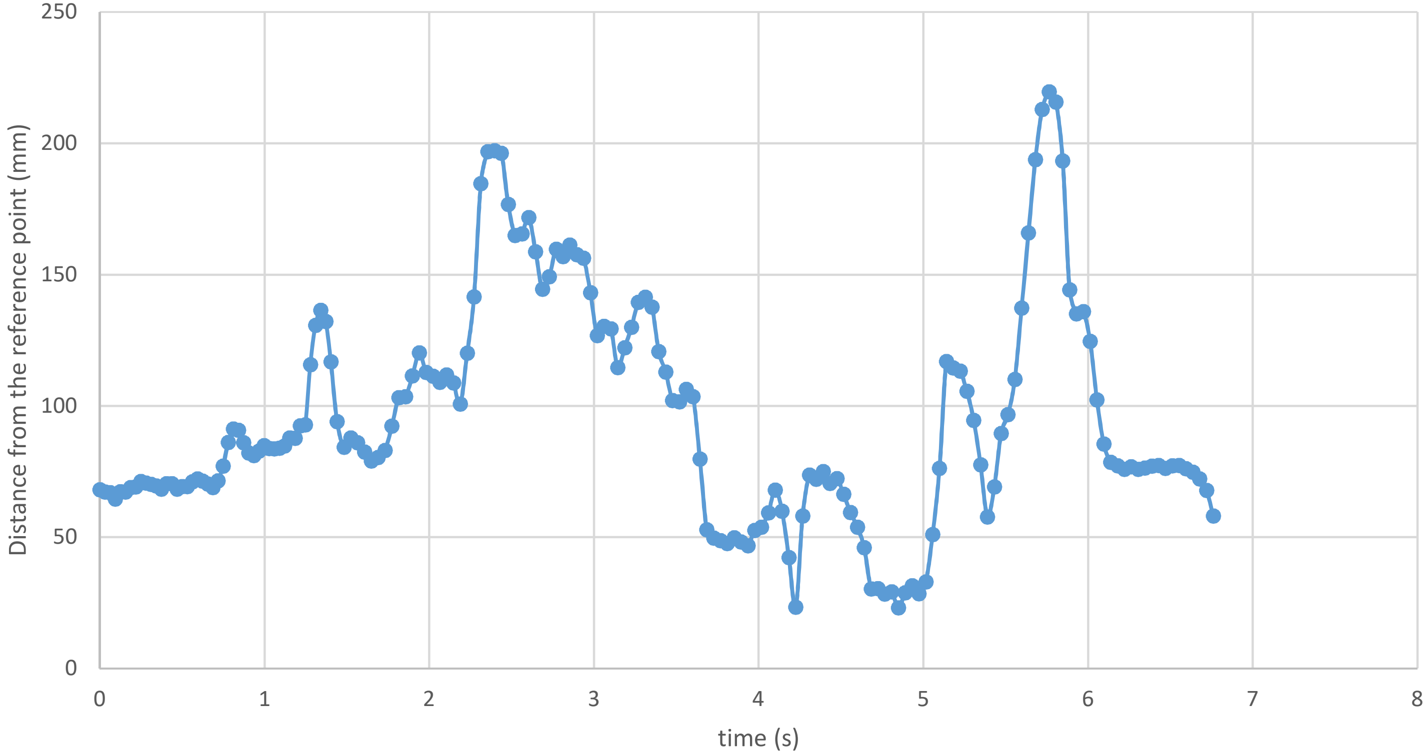


ImajeJ can track the particle

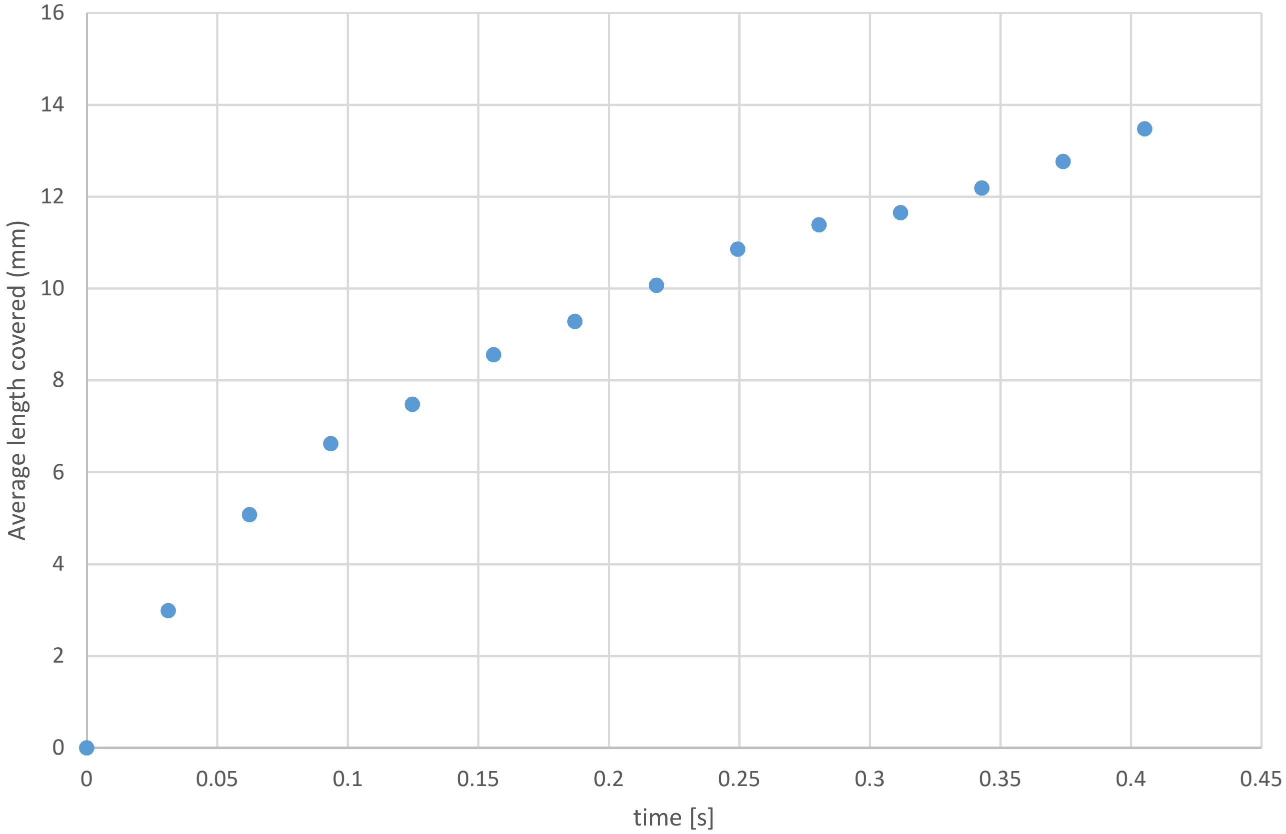
With particle tracking it is possible to convert the video into a series of coordinates.



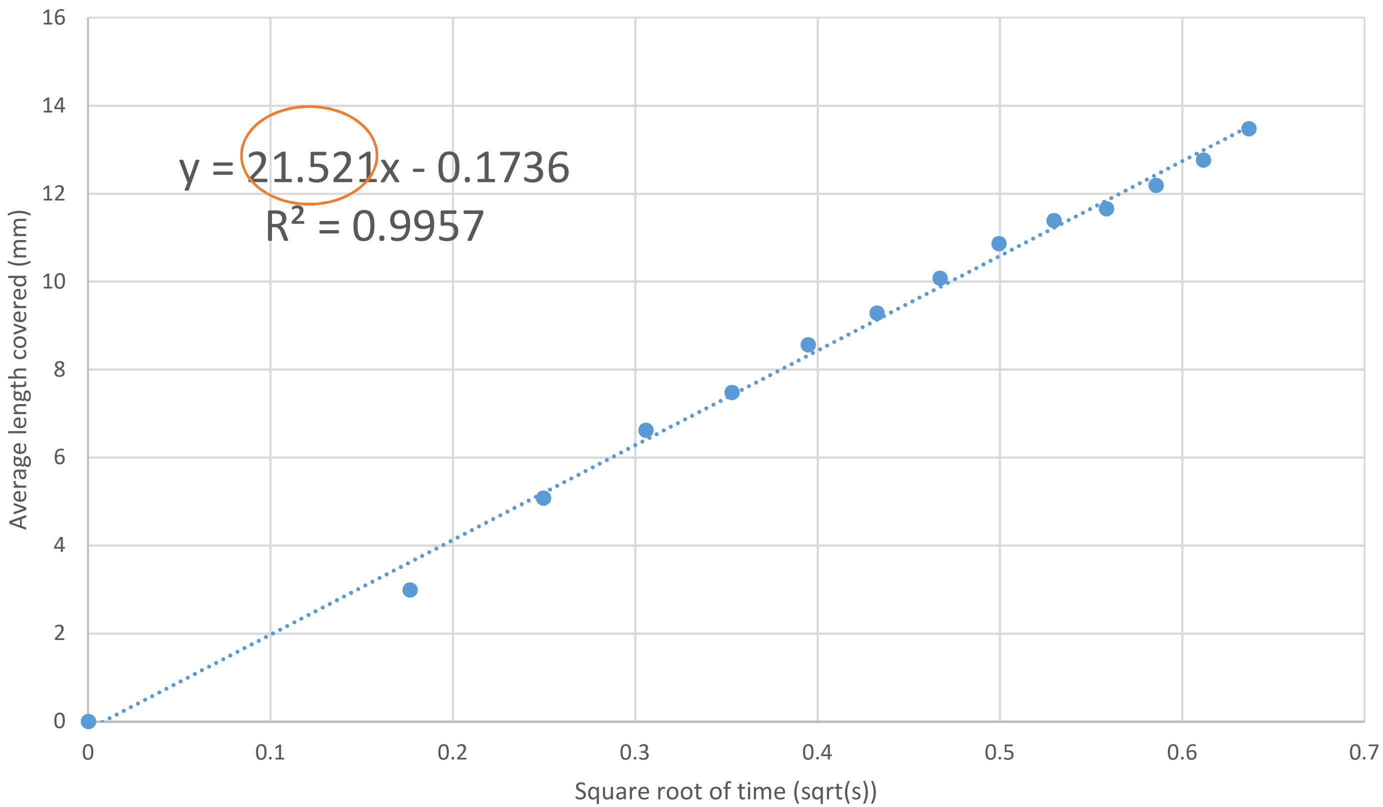
The distance from the origin shows a typical random fluctuation



From multiple particles the average track length over time can be calculated.
(it is also possible to estimate it from one recording)



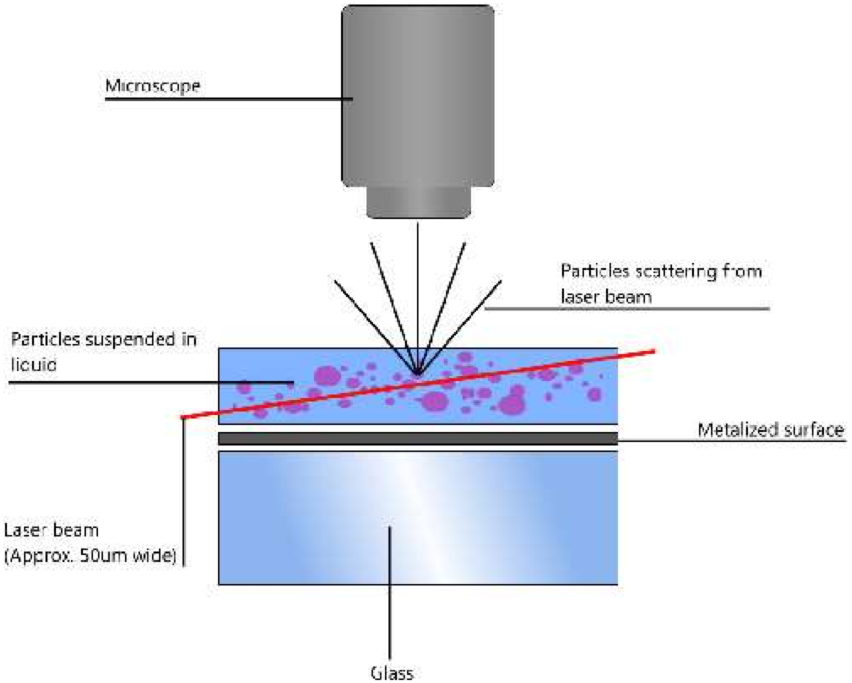
$$R_{average} = \sqrt{2 * D * t}$$

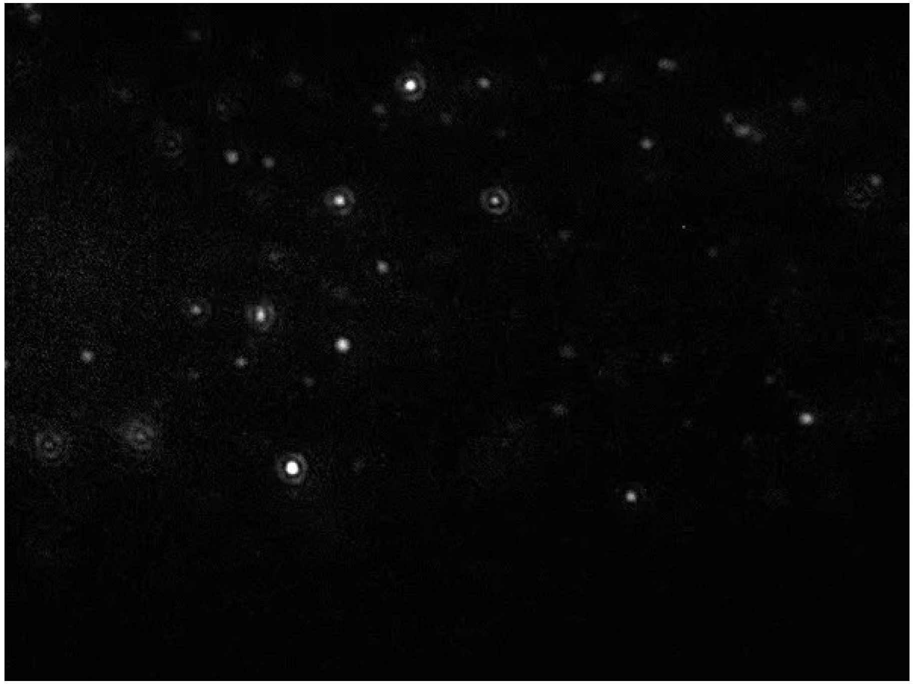


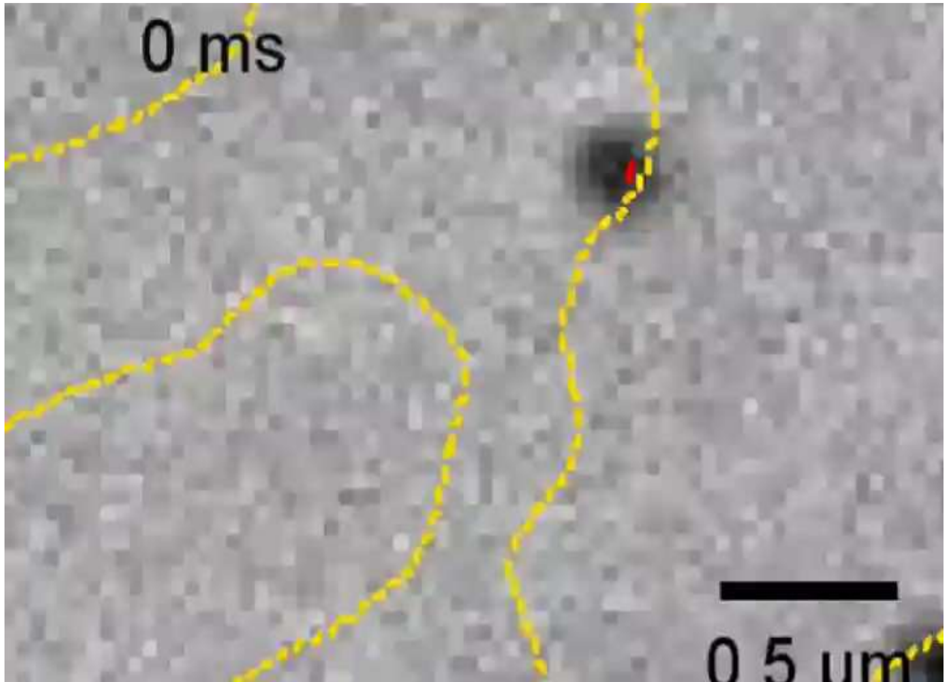
$$\sqrt{2 * D} = 21.521 \frac{mm}{\sqrt{s}}$$

$D_{apparent}$ = 231 mm^2/s

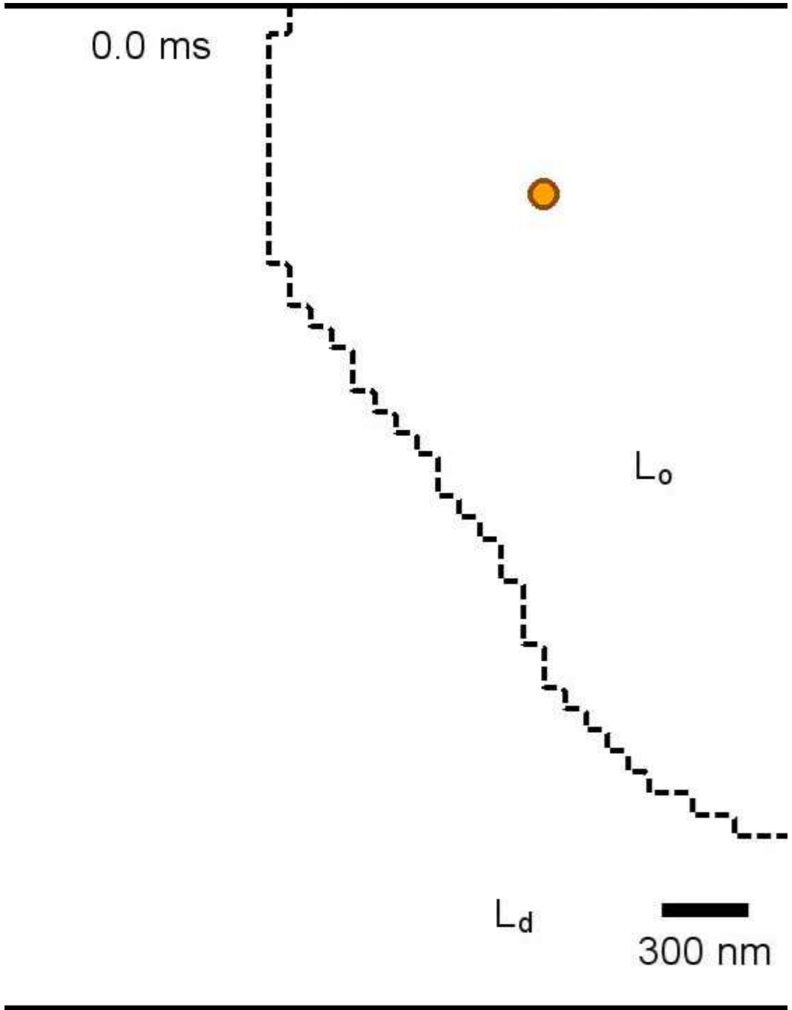
Nanoparticle tracking analysis (NTA)







Tracking gold nano-spheres in the lipid membrane to see the different viscosity (different diffusion coefficient) pars. Faster diffusion reflects greater diffusion coefficient (lower local viscosity)



Wu et al, Scientific Reports, Vol 6, 20542 (2016)