Fluorescence imaging of Thermophoresis
Thermophoresis of DNA
Thermophoretic Trapping of DNA

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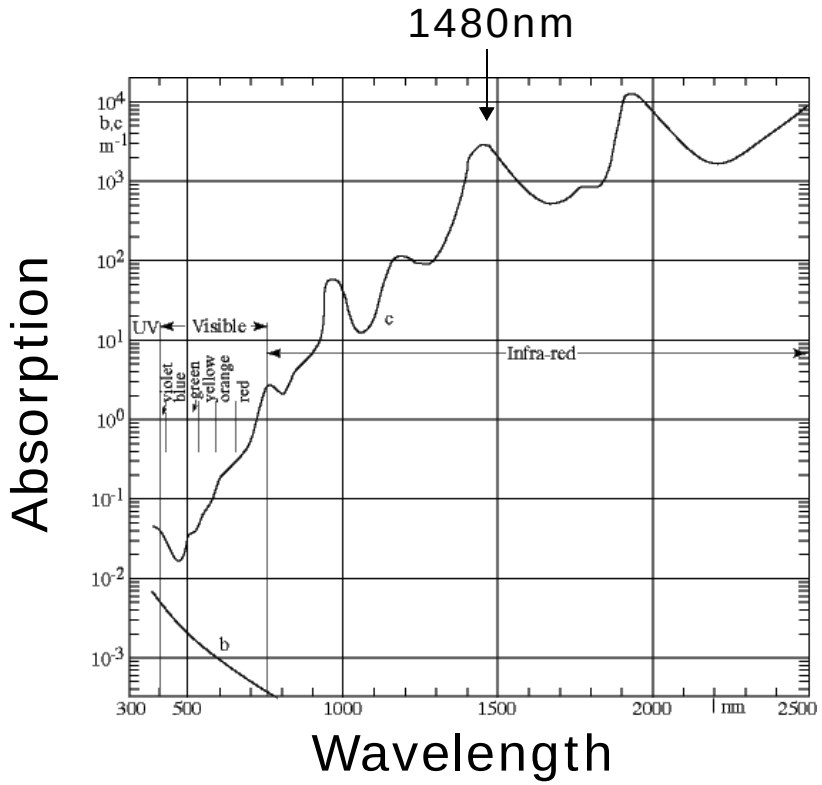
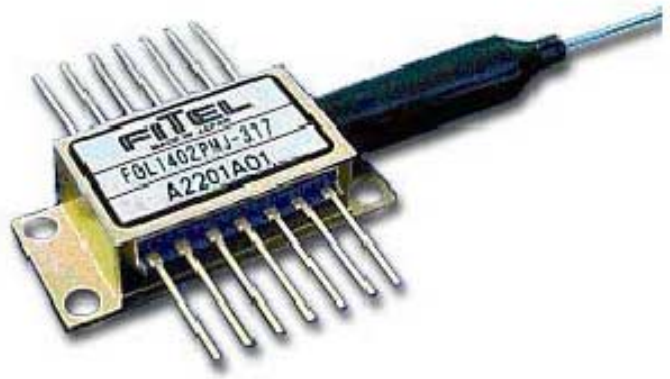
Rockefeller University

Infrared heating

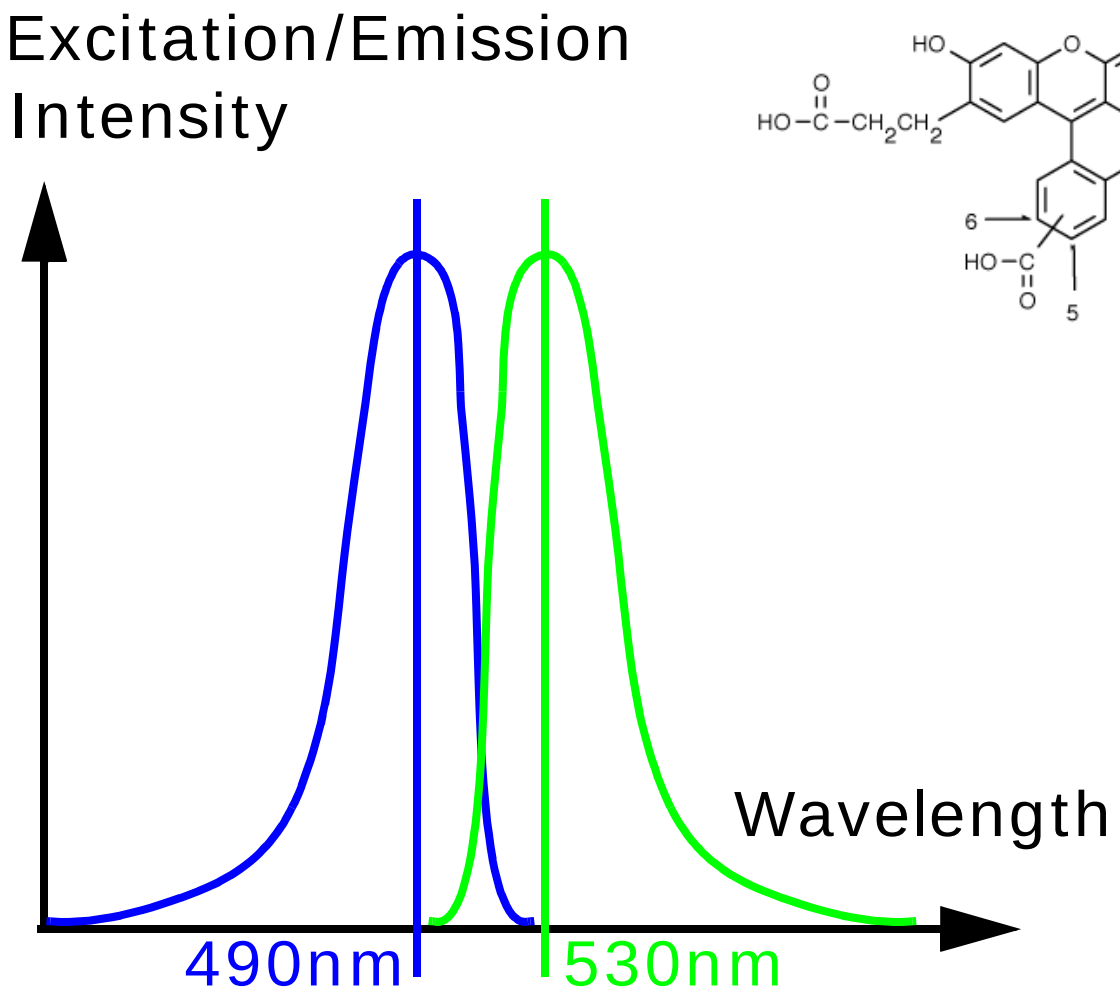


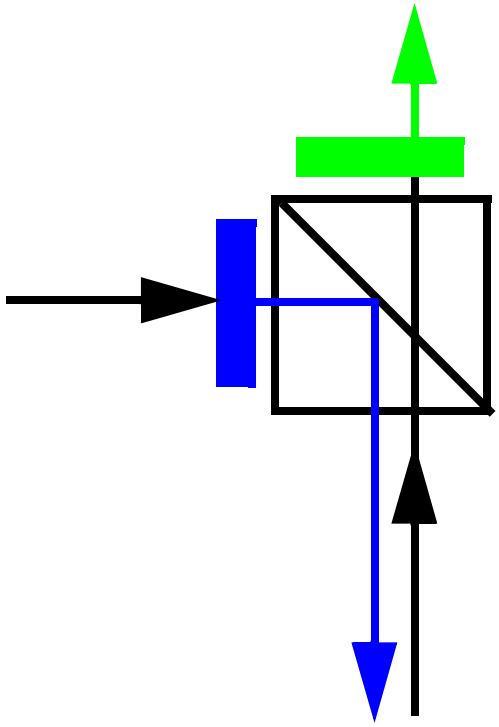


1480nm, 100mW

Fluorescence Microscope

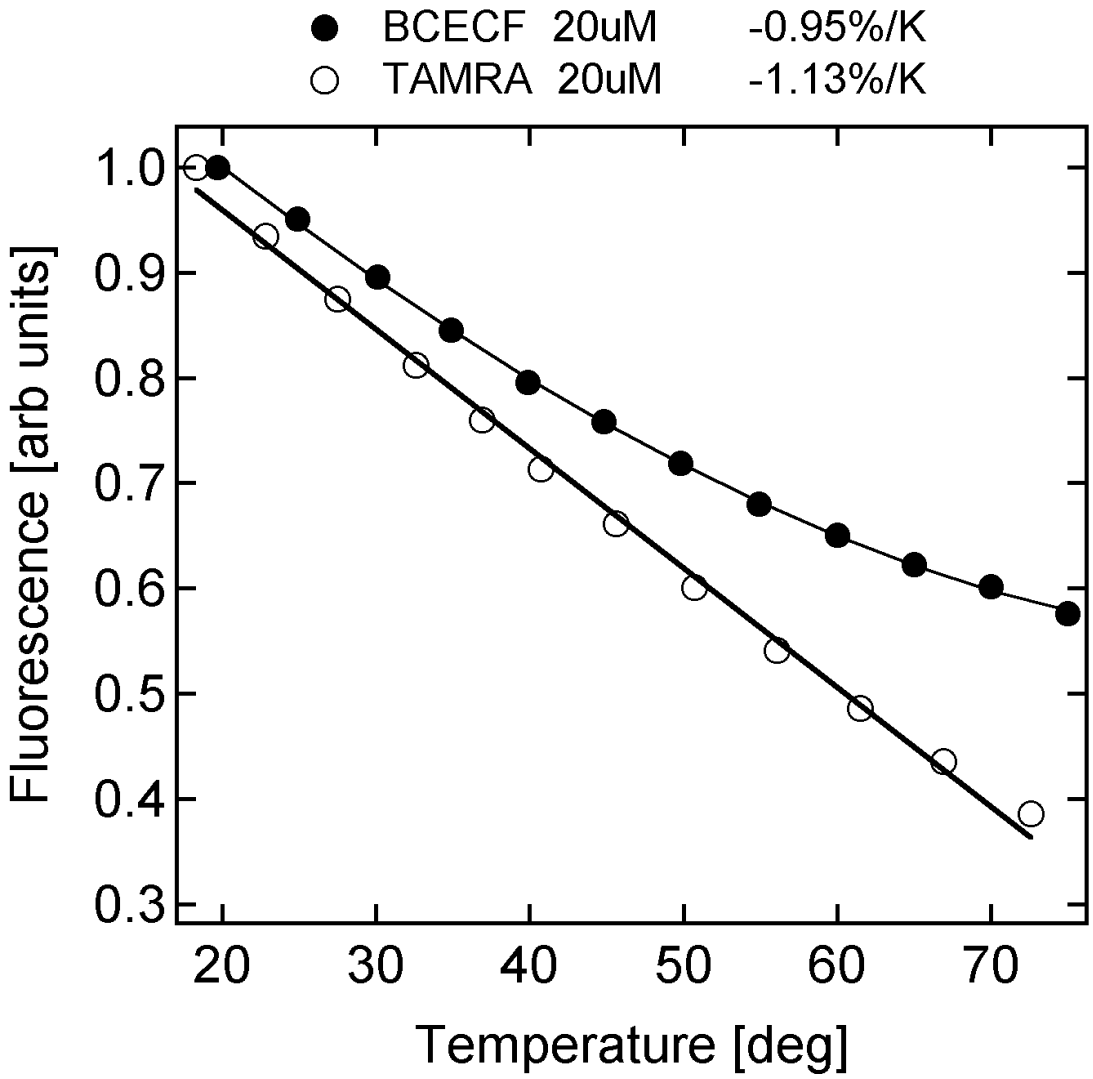
Fluorescent Dyes



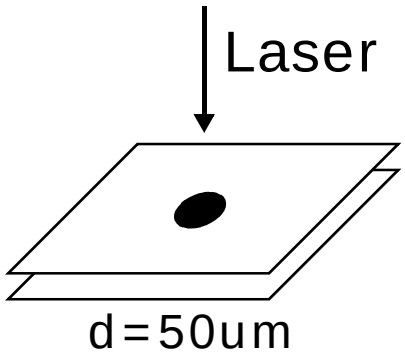


Using Dye Molecules as Thermometer

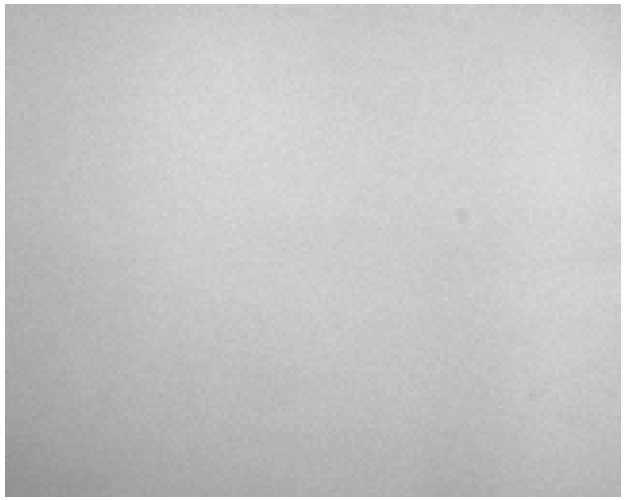
Temperature -> pH of TRIS -> pH Probe



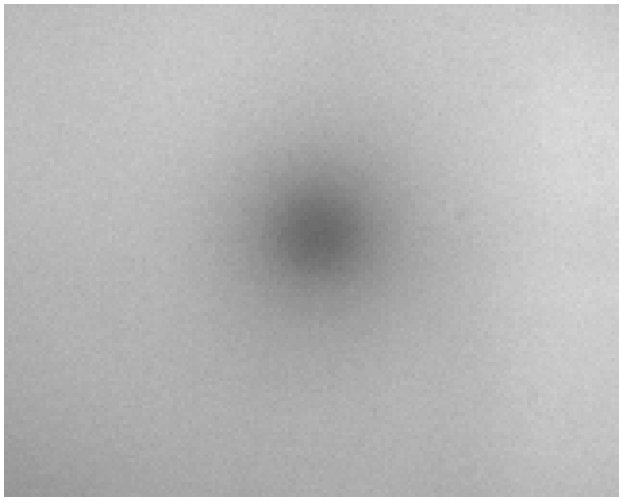
Imaging Temperature



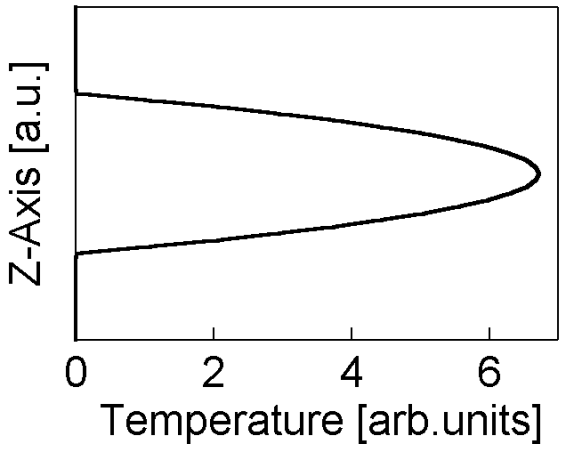
Laser off: cold



Laser on: hot

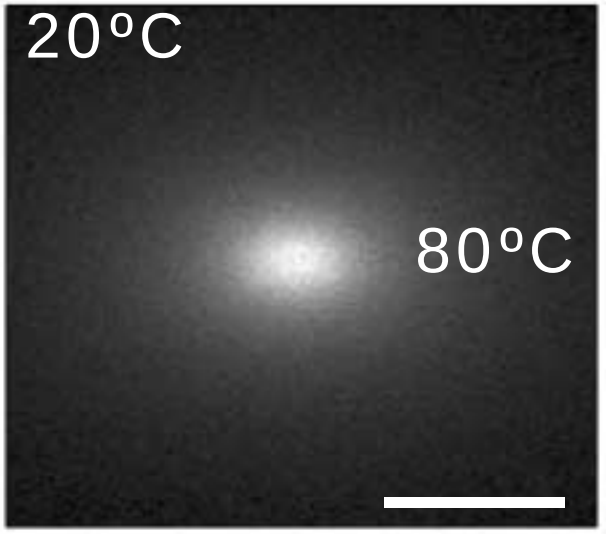


z-Profile



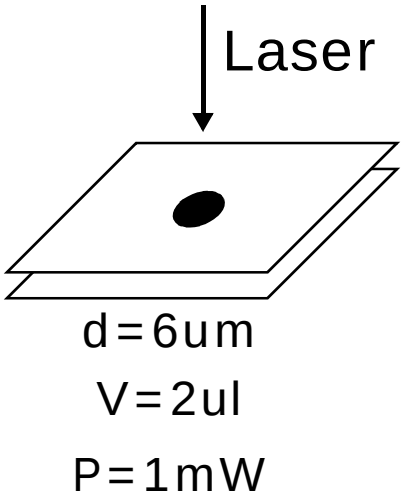
Temperature Image

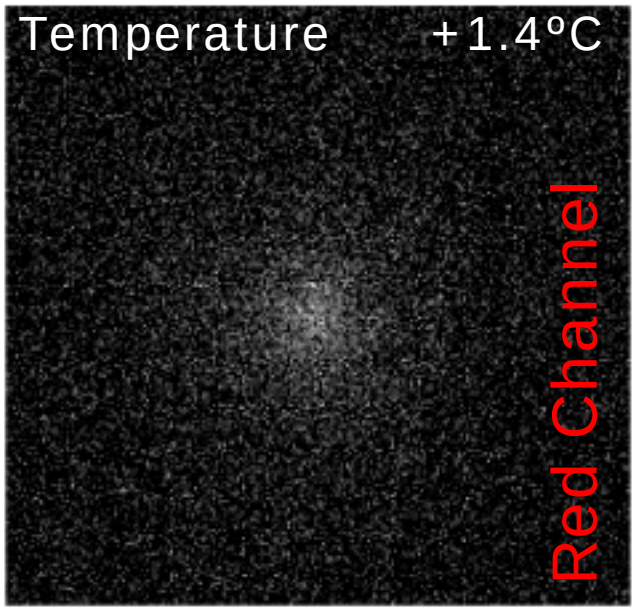
(z-average)

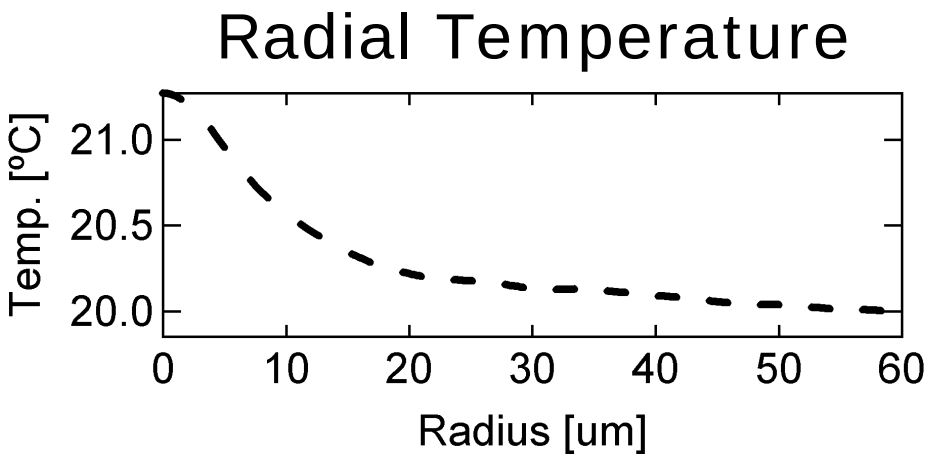


100um

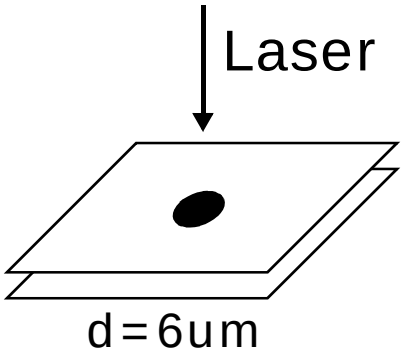
Local, mild heating

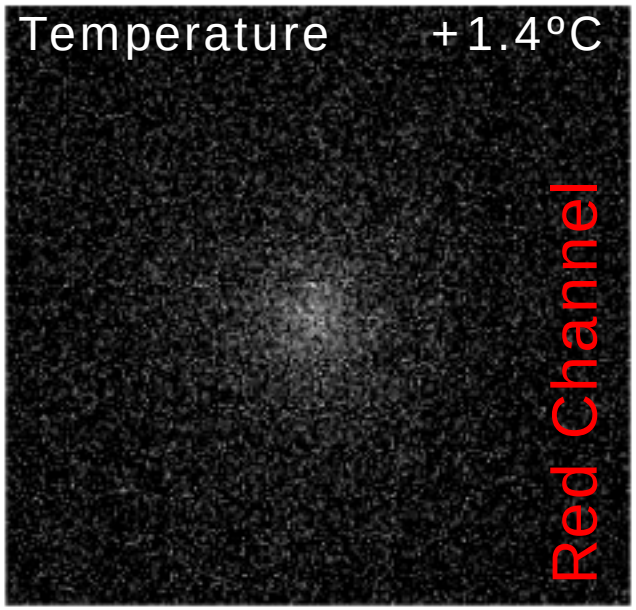


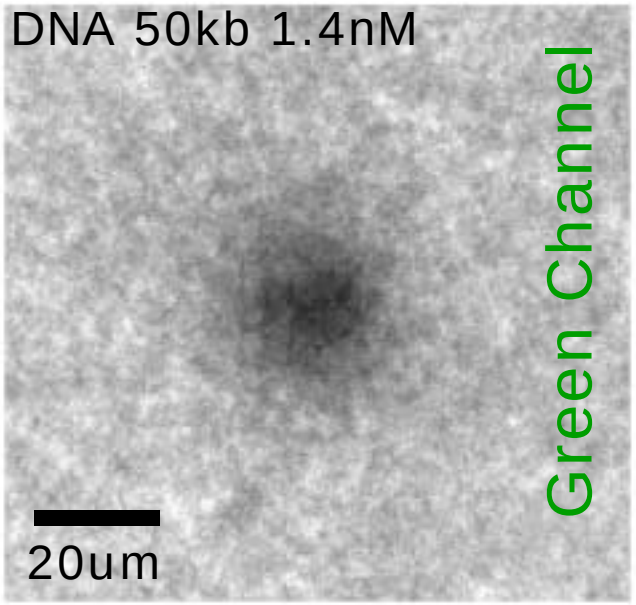




Depletion of DNA from heat

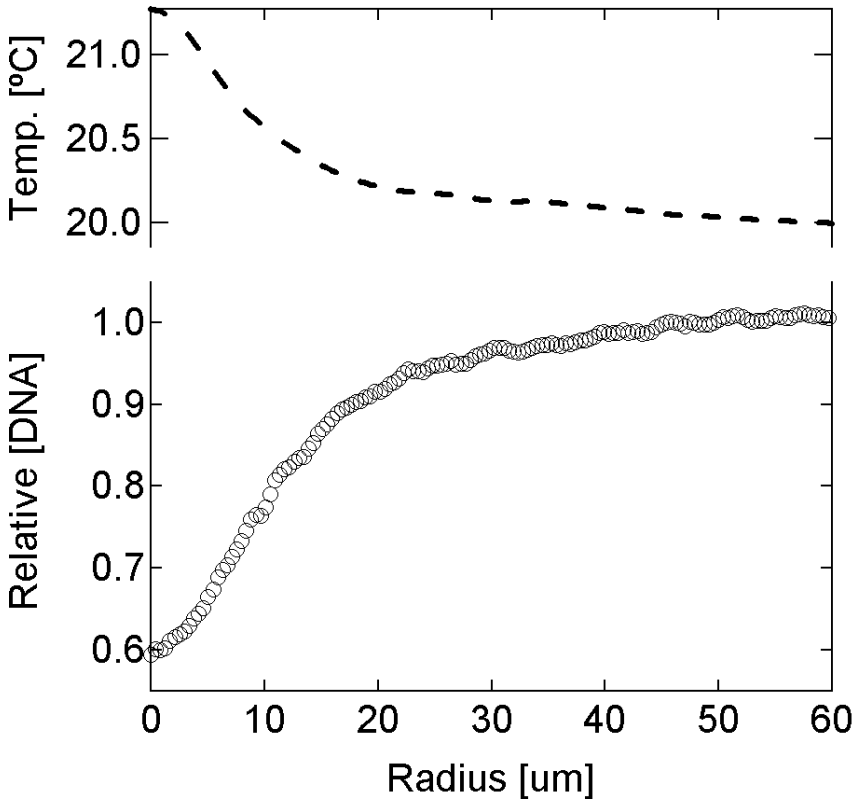






t=300s

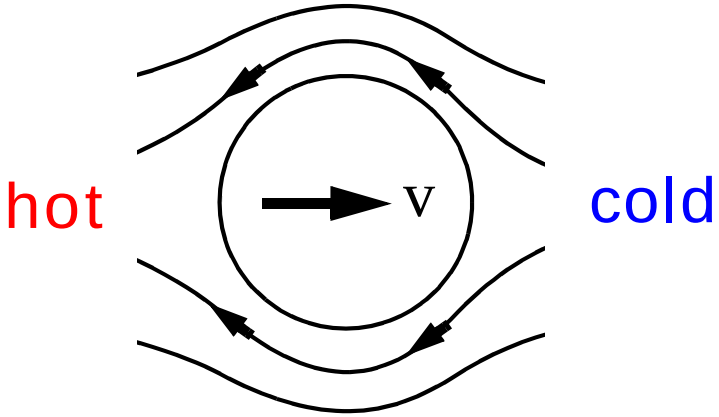
Radial Distribution

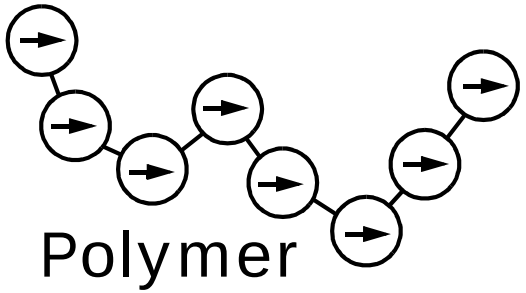


Exclude Artefacts

- no optical trapping
- no temp. dep. of DNA stain
- low convection

Thermophoresis

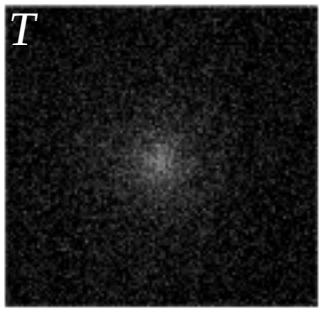




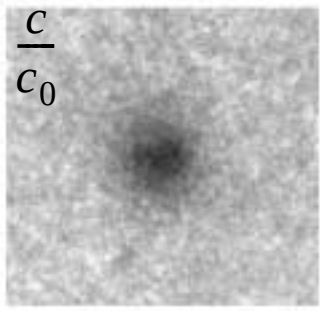
Extension of 1. Fick's Law

$$j = -D\nabla c + D_T c(1-c)\nabla T \overset{!}{=} 0 \xrightarrow[D_T = \text{const.}]{} \frac{c}{c_0} = e^{-\frac{D_T}{D}(T-T_0)}$$

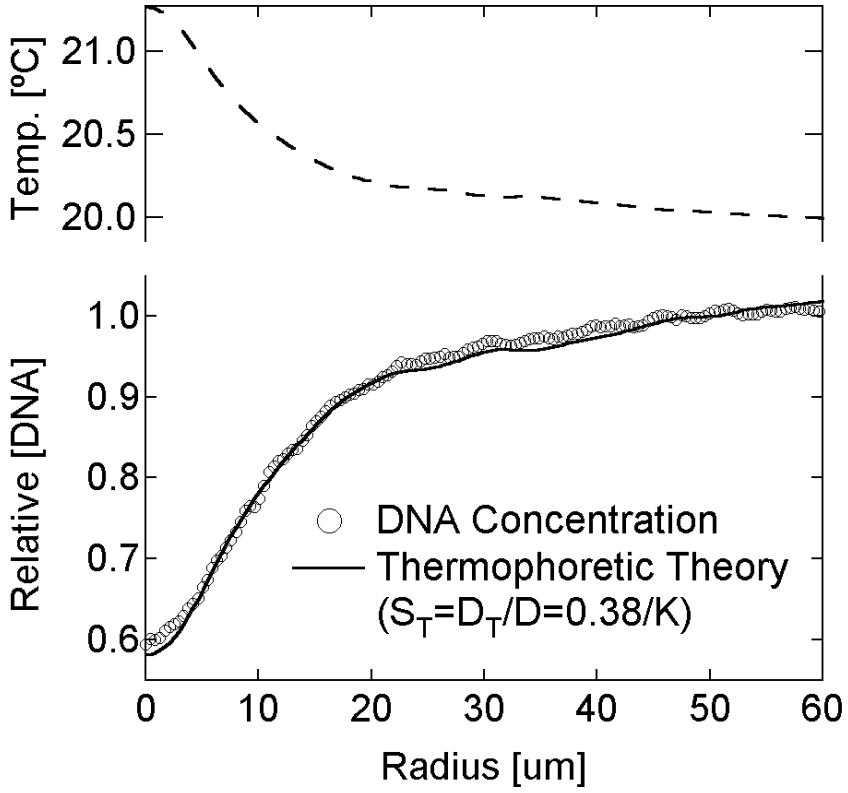
Thermophoresis of DNA - Fit



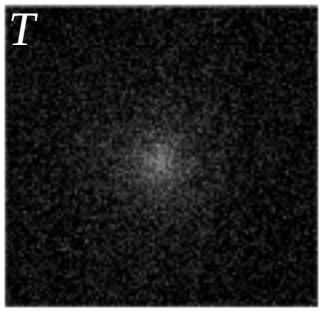
$$\frac{c}{c_0} = e^{-\frac{D_T}{D}(T-T_0)}$$



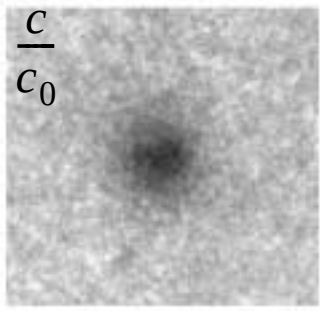
Fit $\frac{D_T}{D}$



Thermophoresis of DNA - Fit

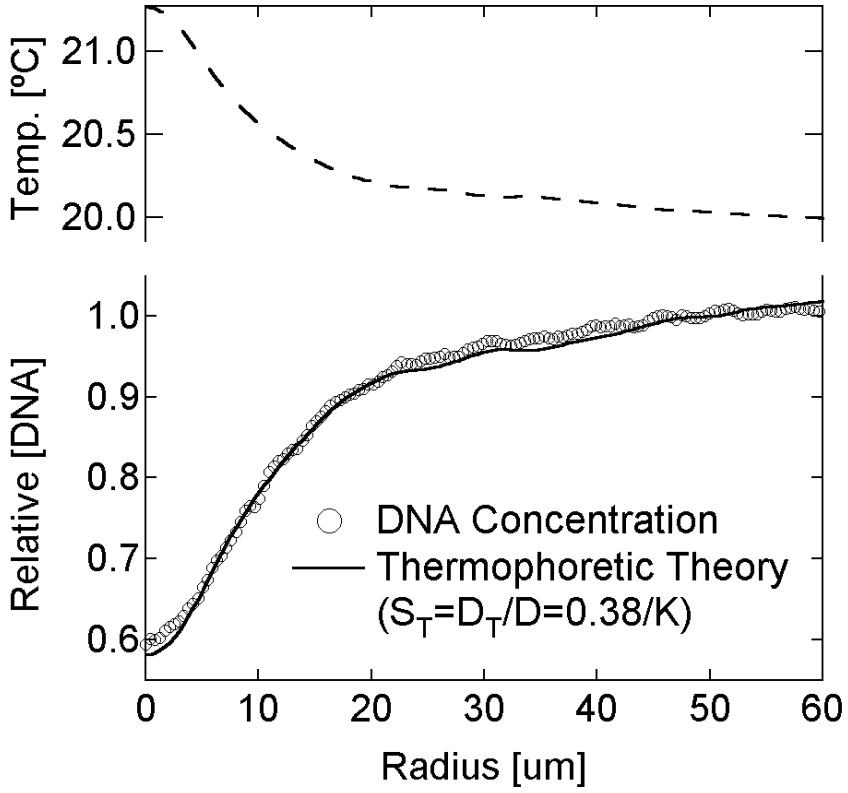


$$\frac{c}{c_0} = e^{-\frac{D_T}{D}(T-T_0)}$$



Fit

$\frac{D_T}{D}$



Backdiffusion

$S_T = 0.38 K^{-1}$

$D = 1.0 \times 10^{-8} cm^2/s$

$D_T = 0.38 \times 10^{-8} cm^2/sK$

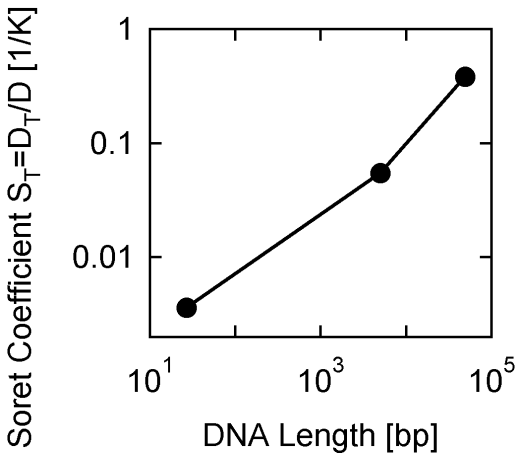
Fluorescence Imaging of Thermophoresis

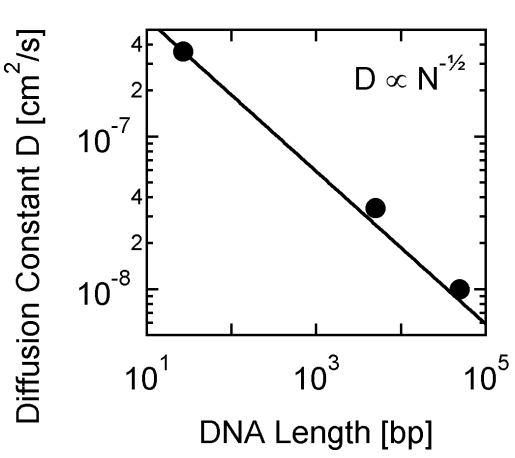
+ Specific staining in fluid mixtures
+ No $\delta c/\delta T$ or $\delta n/\delta T$ calibration
+ Low volume (2µl)
+ Low concentration (nM-µM)
+ Imaging shows preparation artefacts
+ Imaging shows fluid drift
+ Analysis tests for convection
+ Suited for biological probes (proteins...)

- Probably not as precise

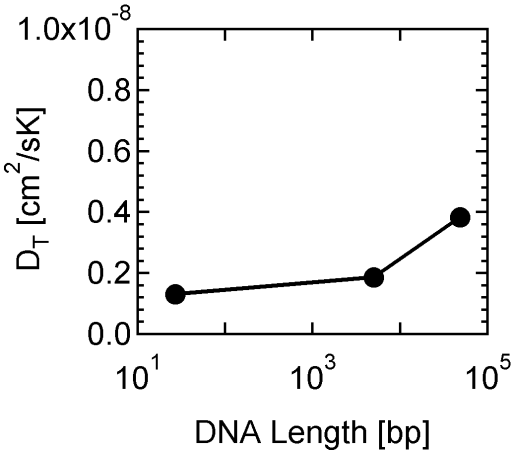
Thermophoresis of DNA

Length dependence





$$\frac{D_T}{D} \rightarrow D_T$$

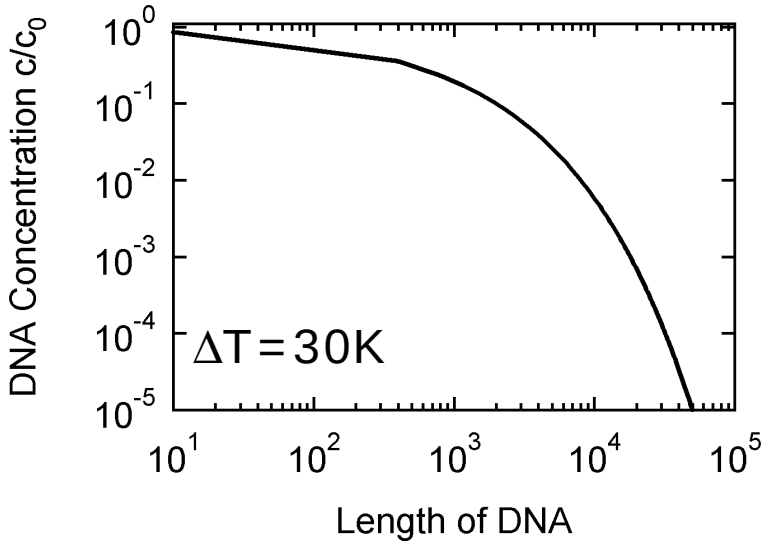


Thermophoresis of DNA

Length dependence

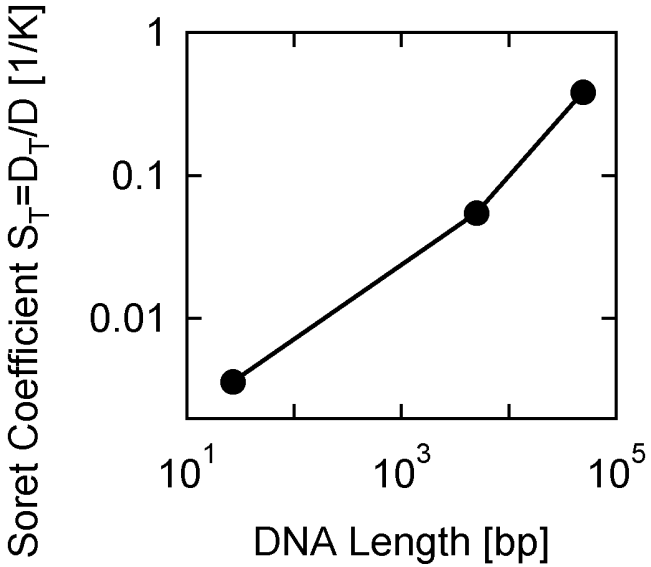
$$D \propto N^{-0.5}$$

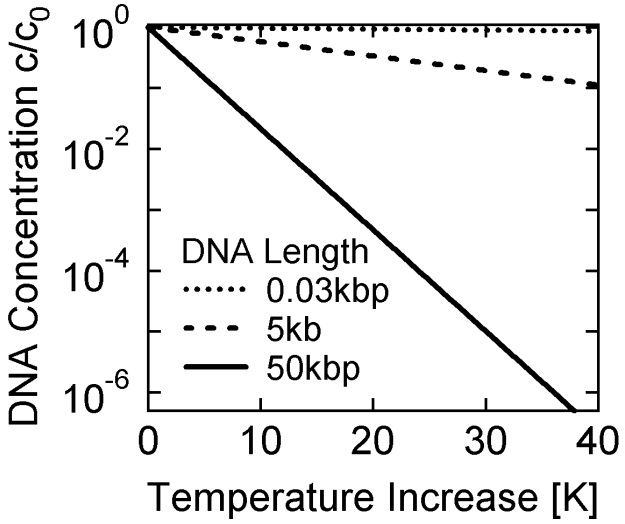
$$\frac{c}{c_0} = e^{-\frac{D_T}{D}(T - T_0)}$$



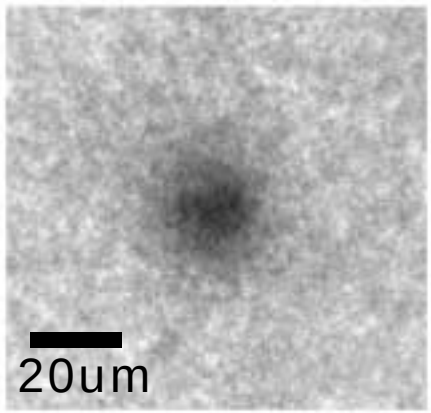
Thermophoresis of DNA

Temperature dependence

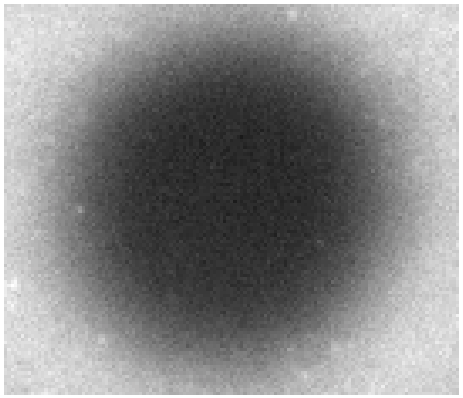




$\Delta T = 1.4K$

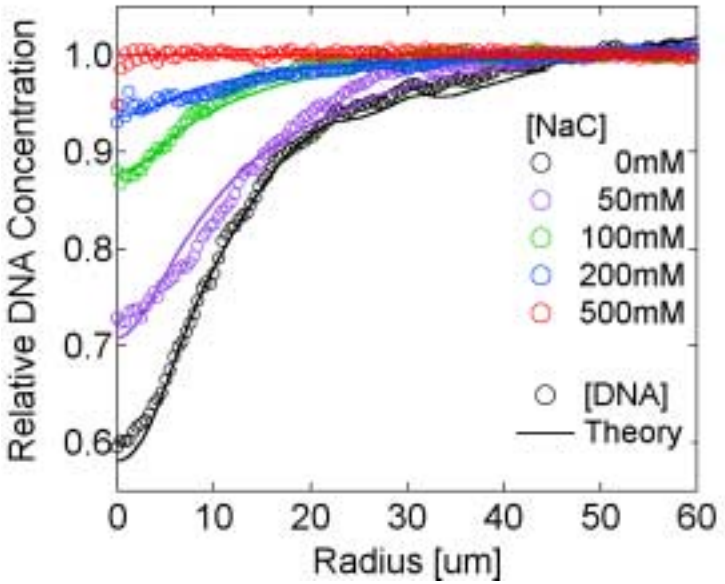


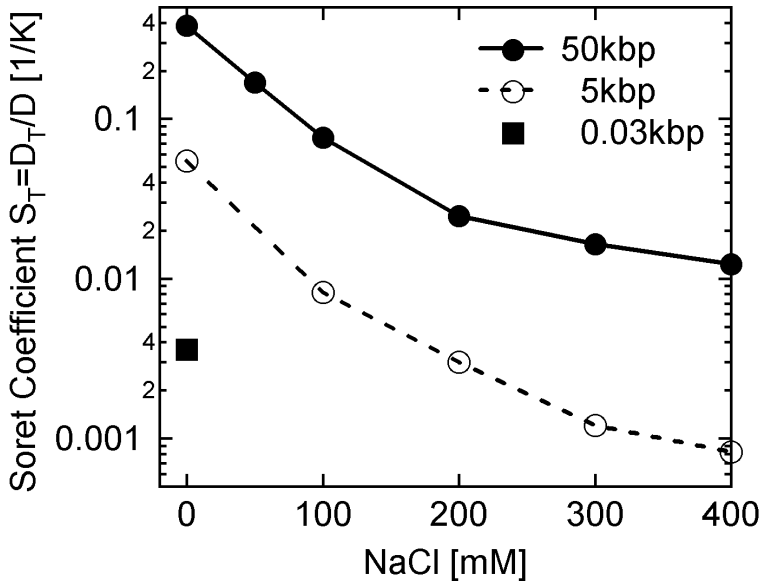
$\Delta T = 25K$



Thermophoresis of DNA

Salt Dependence

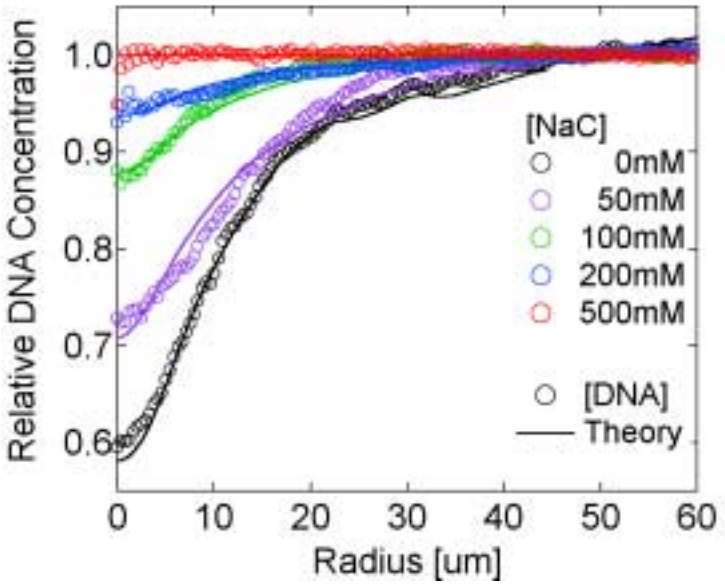


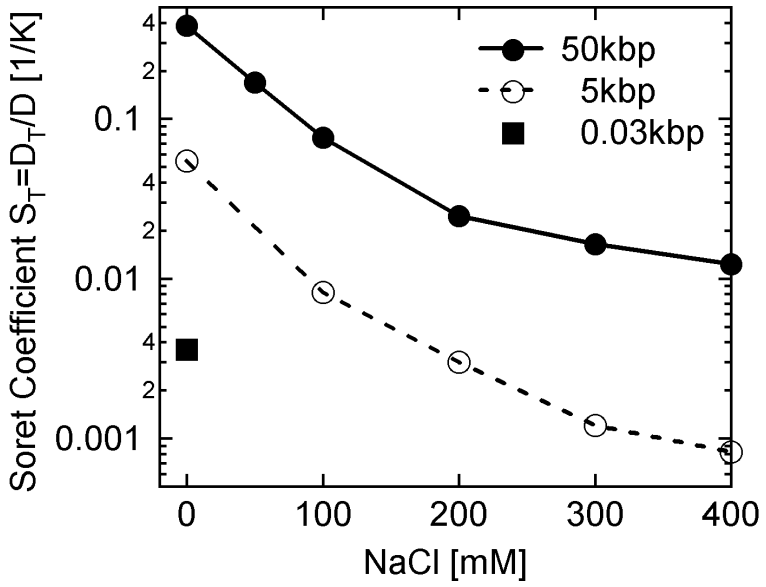


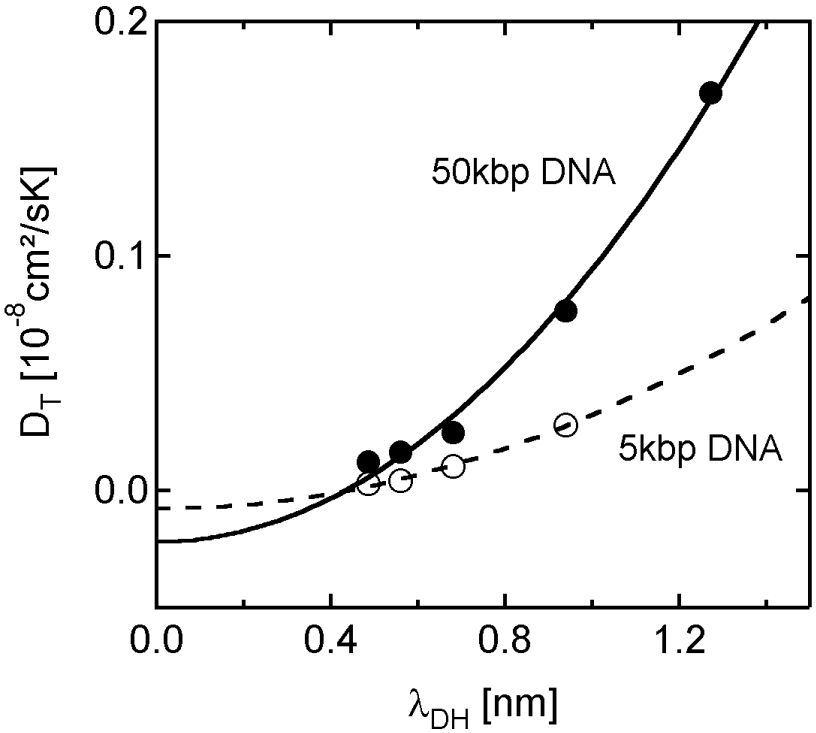
[Similar for 40nm Beads]

Thermophoresis of DNA

Salt Dependence

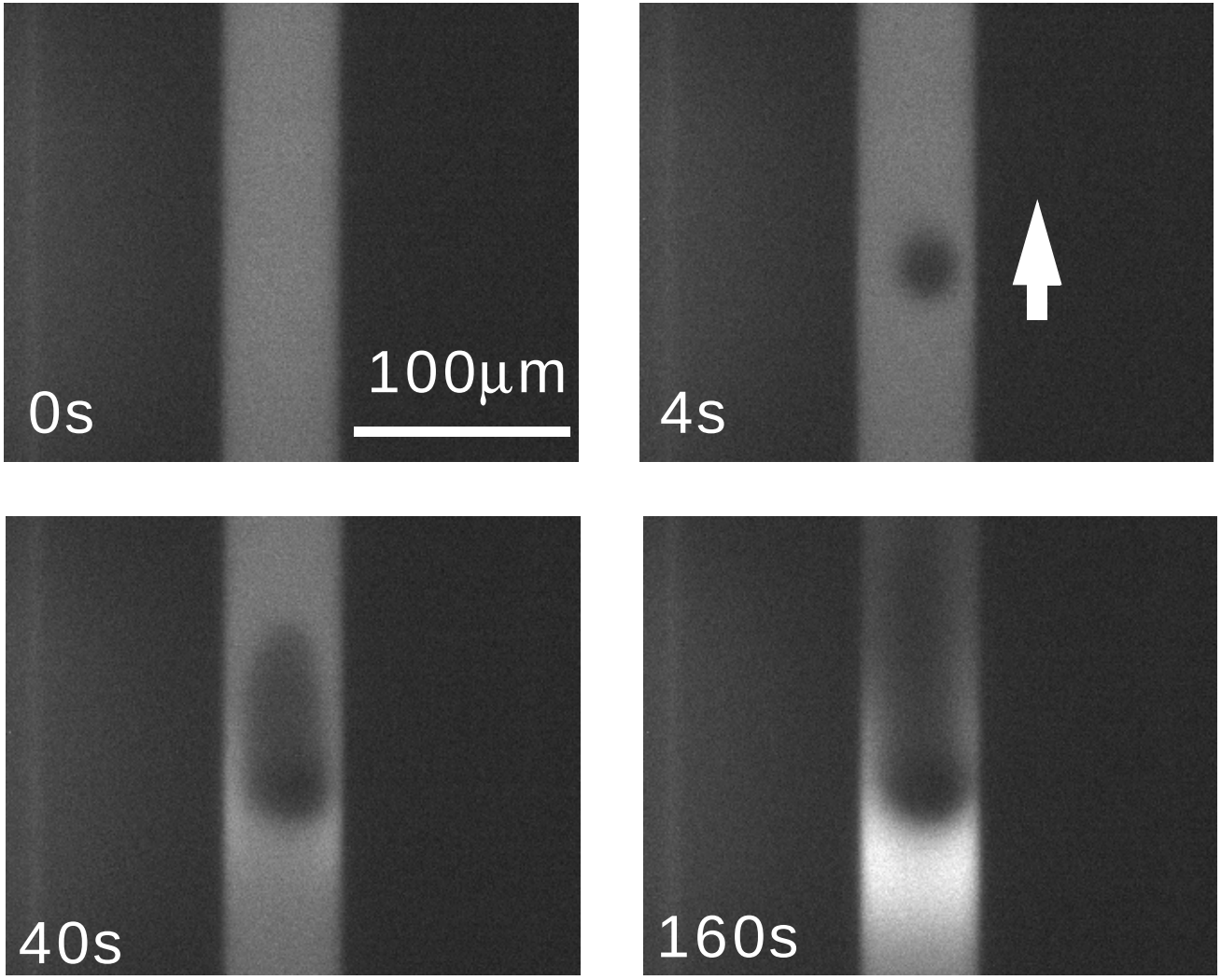






[Similar for 40nm Beads]

Thermophoresis against a microfluidic flow

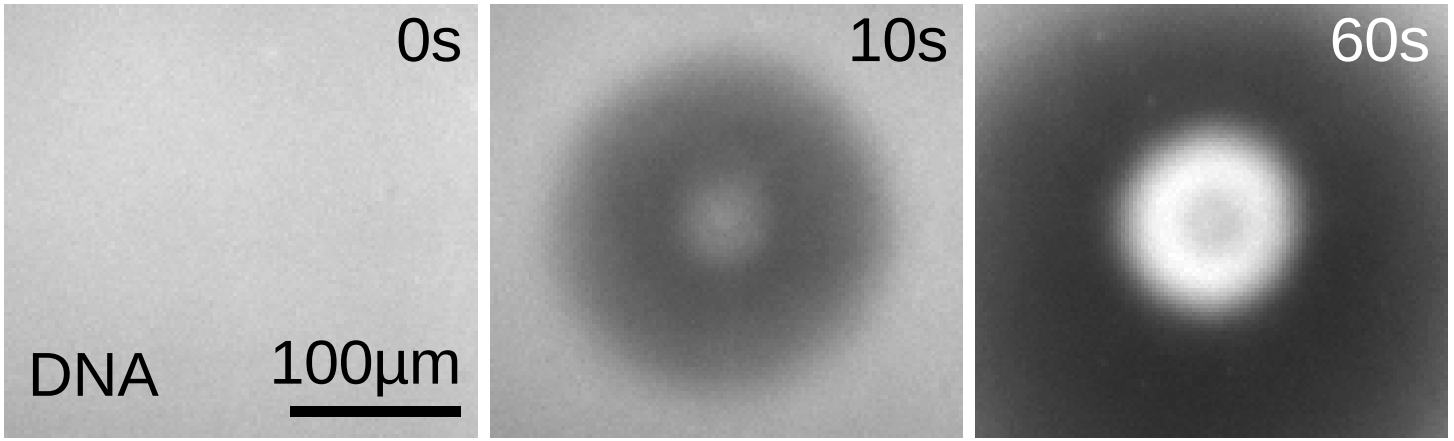


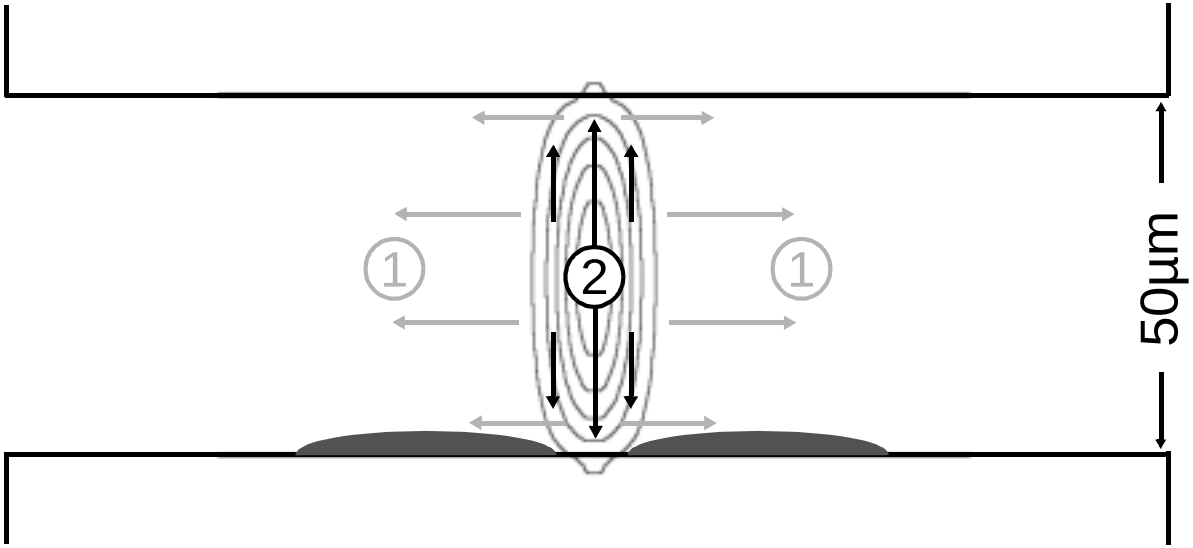
Trapping DNA by Temperature

Rendering Depletion into attraction

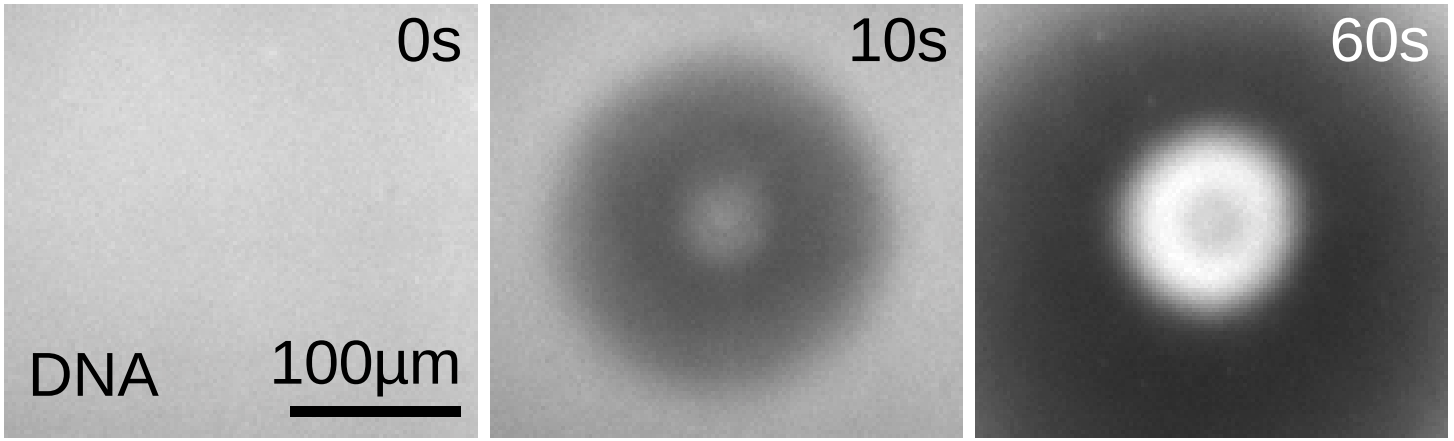
Braun & Libchaber, Phys. Rev. Lett., accepted

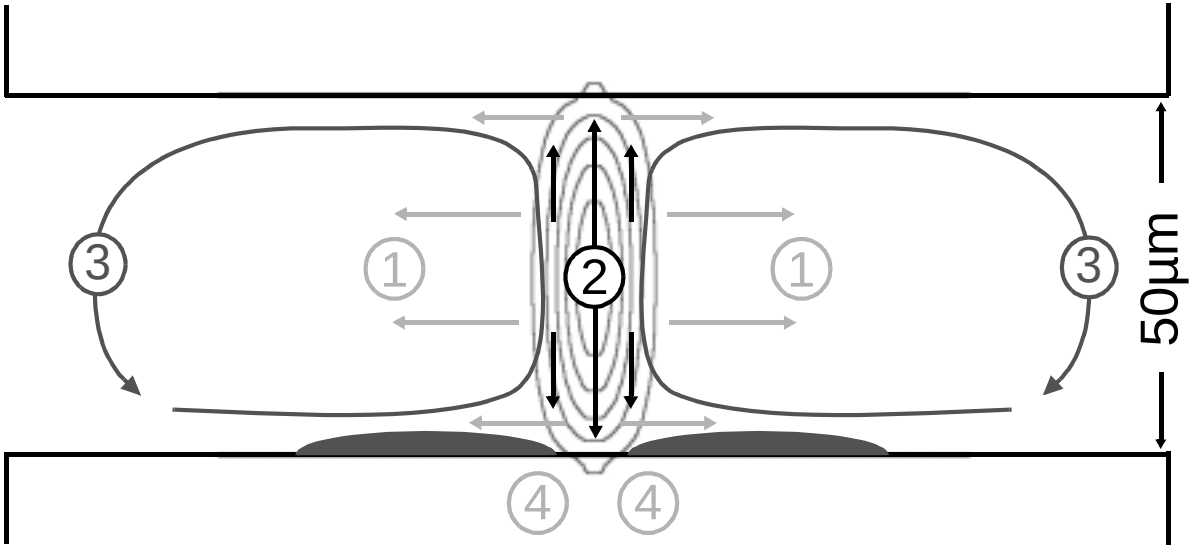
Trapping DNA by Temperature





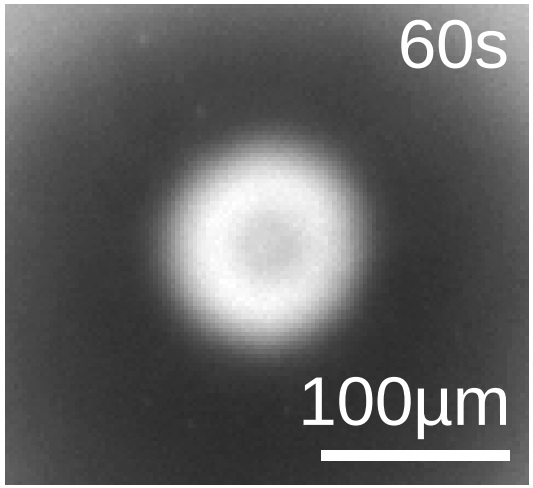
Trapping DNA by Temperature

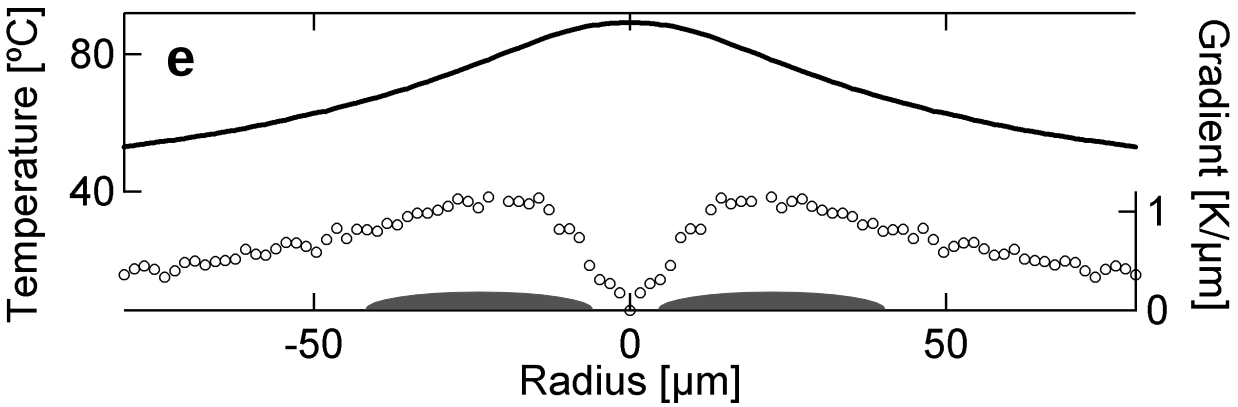




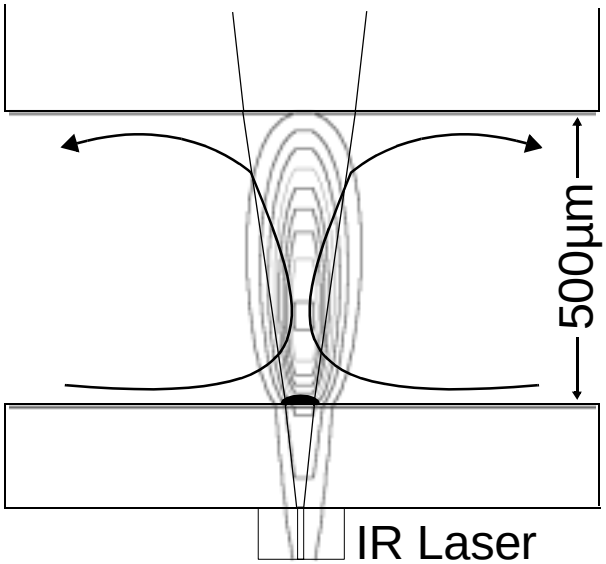
Concentration increase approx. 60-fold

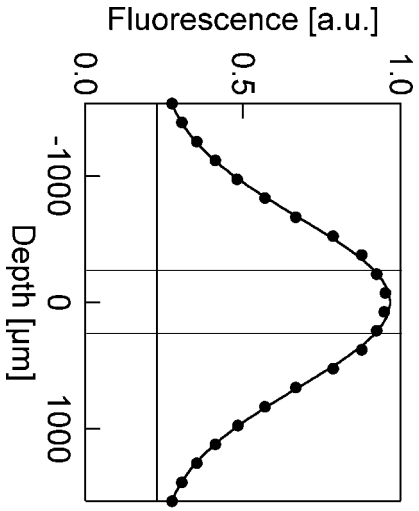
Ring Structure

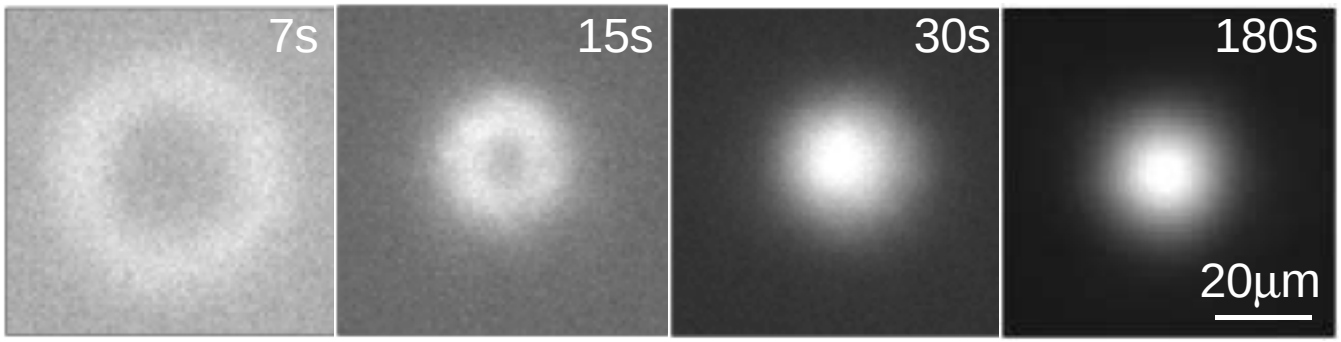




Strong accumulation

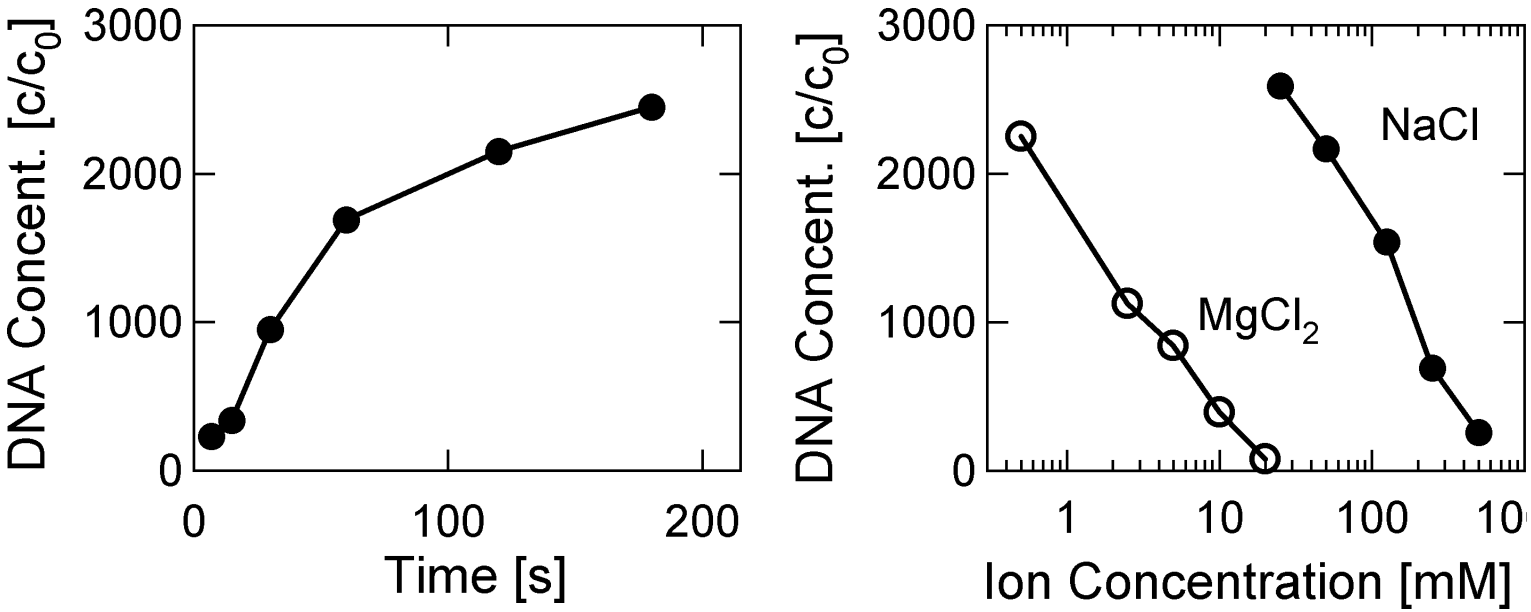




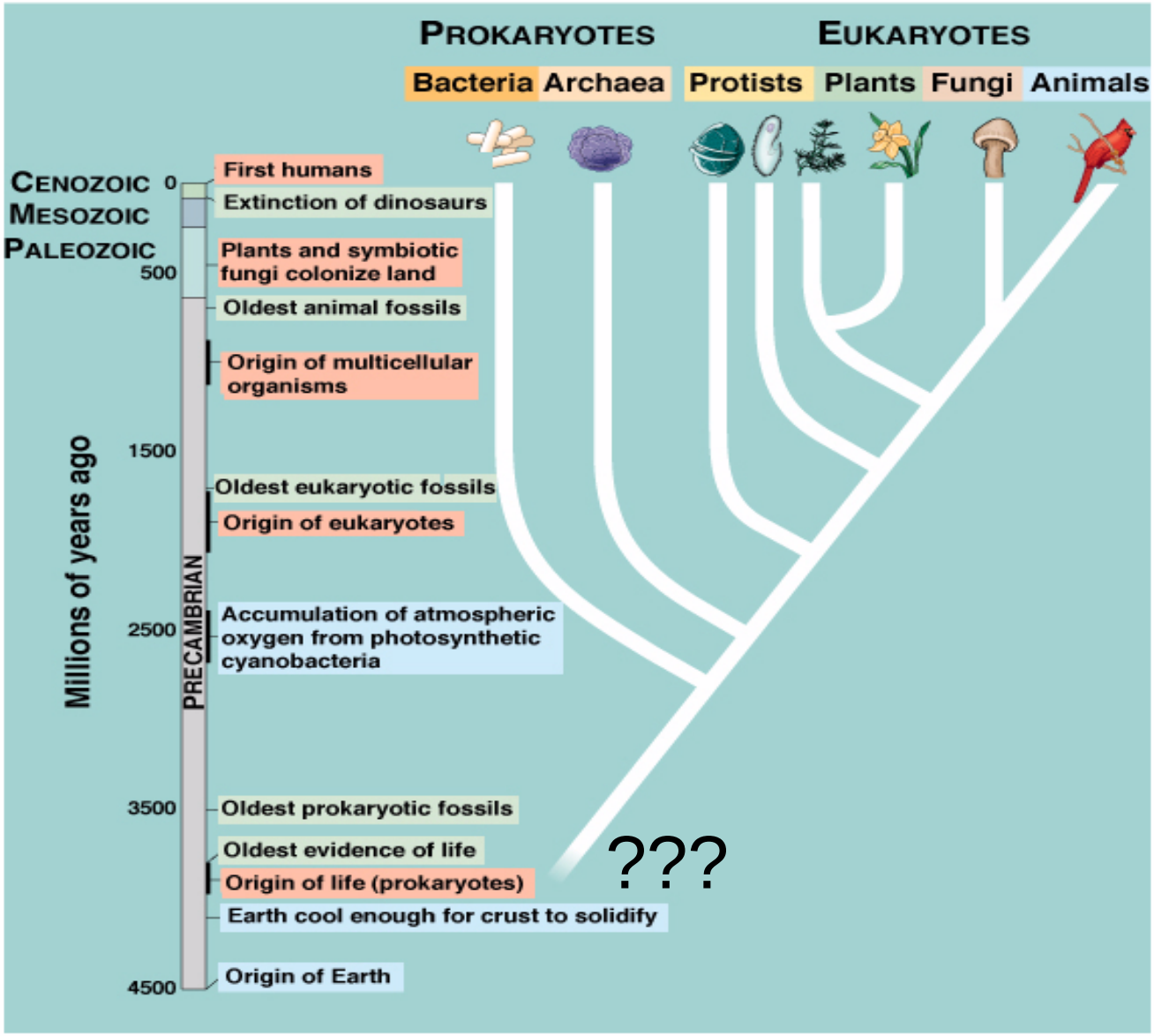


I/I_0=2.3	3.4	9.5	24.5
c/c_0=230	340	950	2450

Strong accumulation

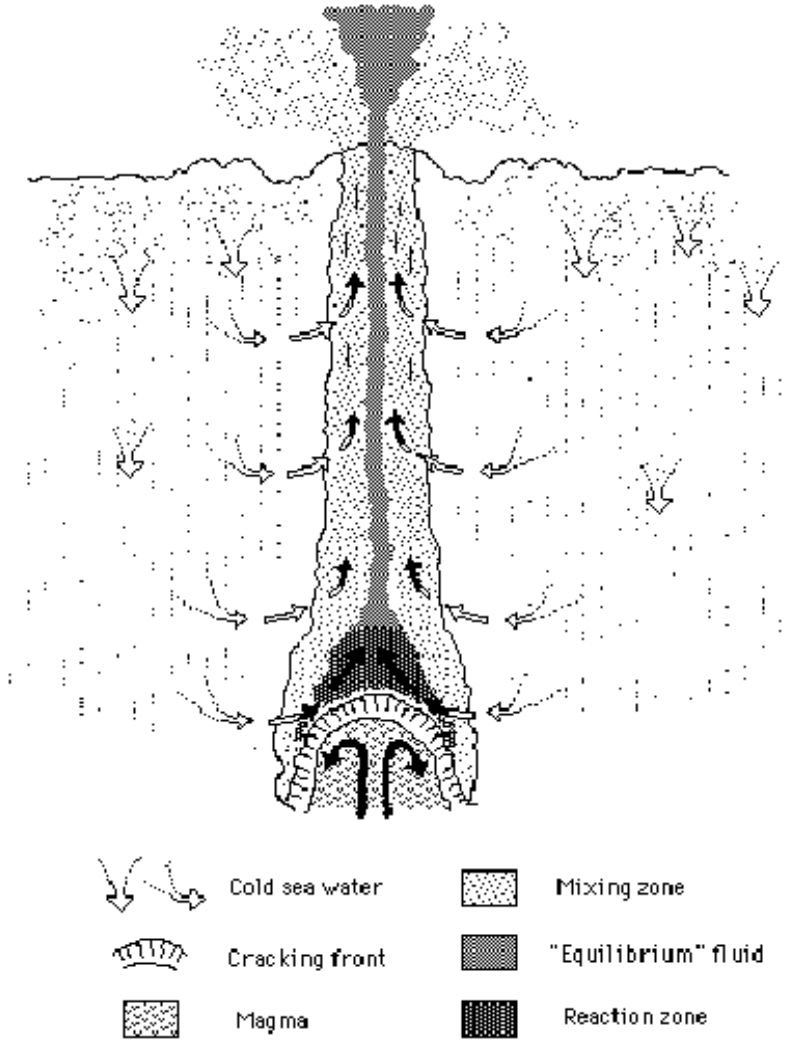


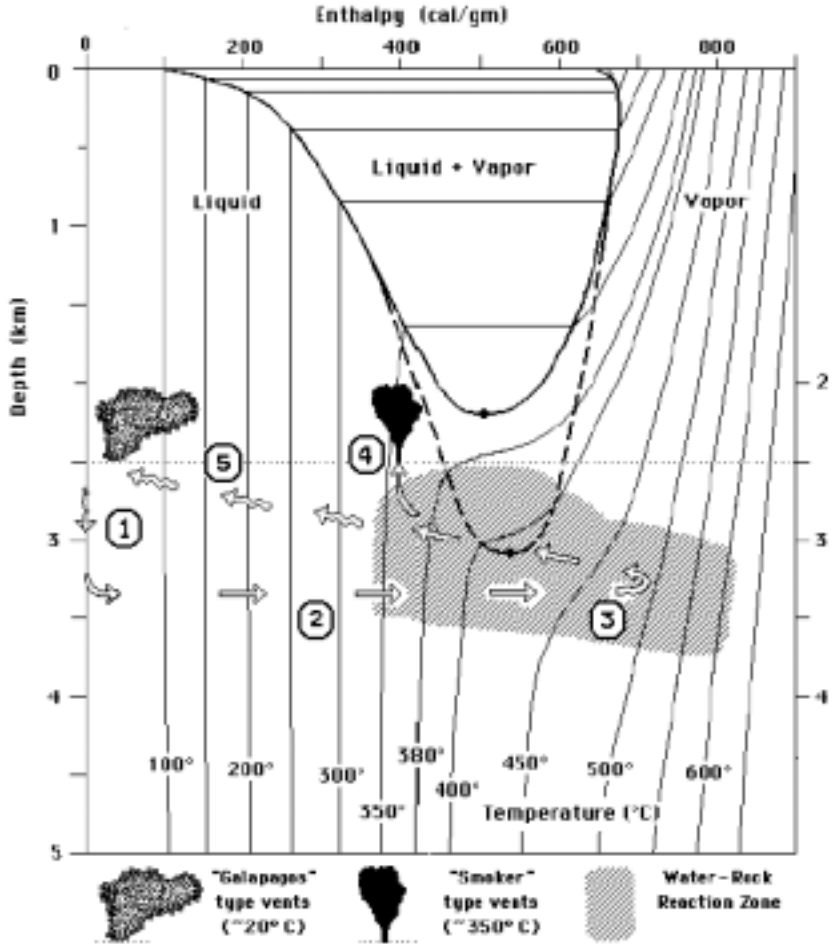
Origin of Life: new physical aspects?



Thermophoretic trapping in sea floor?

Hydrothermal vents





Constant Heating in small volumes

can

Accumulate DNA to microscopic points

and

Apply fast temperature cycling

=> Prebiotic Reactor?

Future Addition to Fountainebleau-Benchmark?

Lambda-DNA (50kbp)

in water with
150mM NaCl
10mM TRIS-HCl
pH 8.0
25°C

Acknowledgements

Libchaber Lab
Emmy Noether Scholarship, DFG