Le idee della ricerca a lavoro

Il ricercatore propone idee all'imprenditore

Napoli 26-27 Febbraio 2008

Antonio Sasso

Dipartimento di Scienze Fisiche

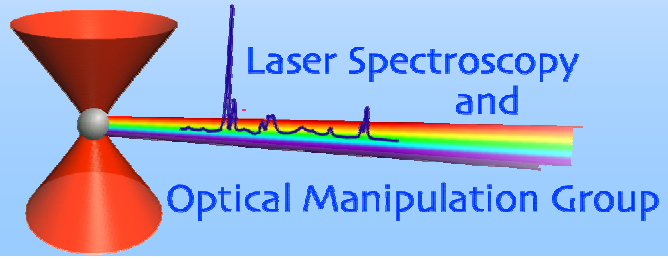
Università di Napoli "Federico II"

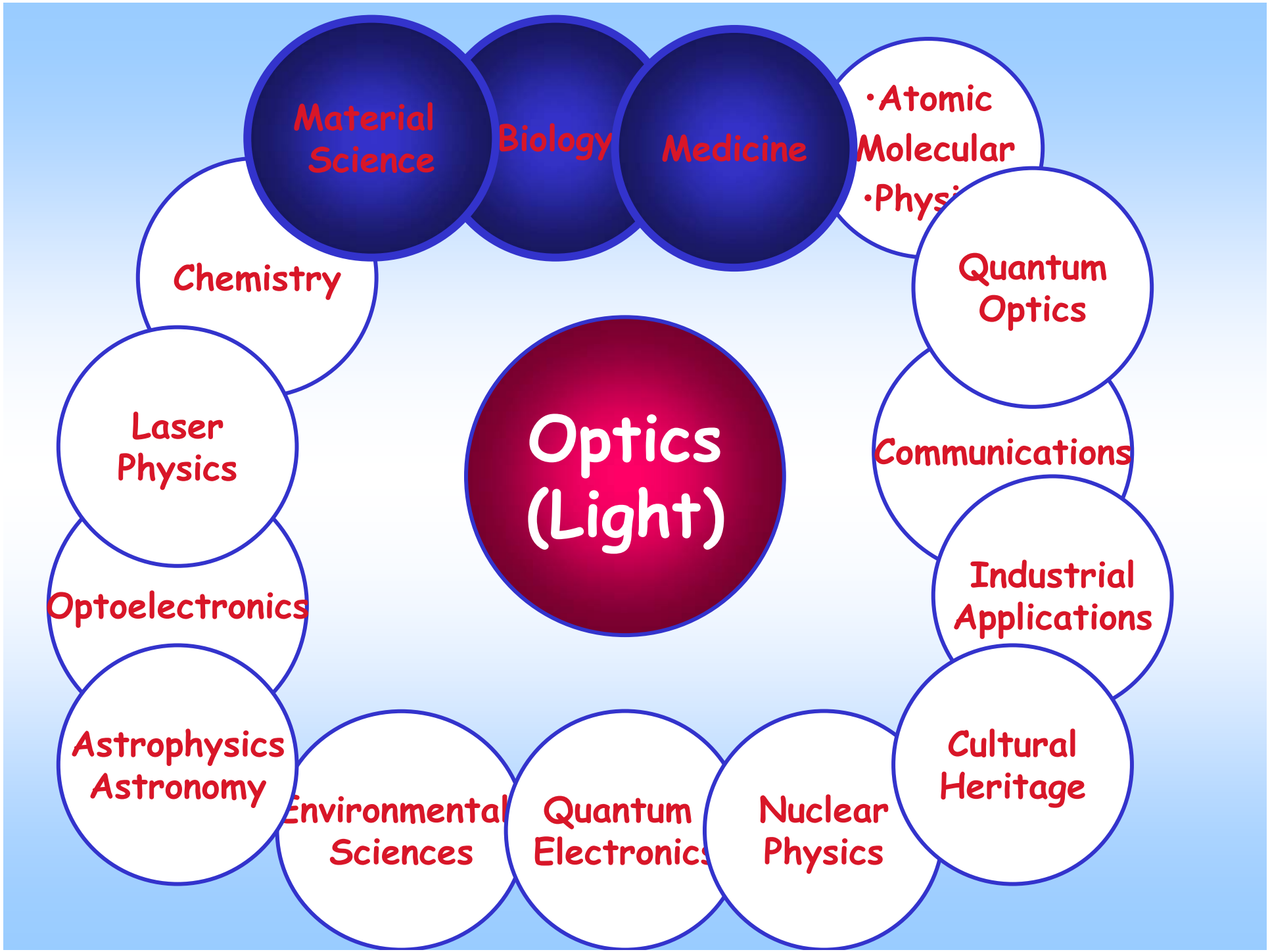
and

Consorzio Nazionale Interuniversitario per le Scienze fisiche della Materia

sasso@na.infn.it

Analisi chimica e strutturale di materiali su scala micro e nano-metrica mediante pinzette ottiche




Optics
(Light)
Material
Science
Biology
Medicine
•Atomic
Molecular
•Physi
Quantum
Optics
Communications
Industrial
Applications
Cultural
Heritage
Nuclear
Physics
Quantum
Electronics
Environmental
Sciences
Astrophysics
Astronomy
Optoelectronics
Laser
Physics
Chemistry

1. Micro-reologia di mezzi complessi (VISCOLEASTICITA')

   scala mesoscopica: intermedia tra la scala macroscopica e quella molecolare

2. Analisi Raman di singole particelle

   scala molecolare

Rheology

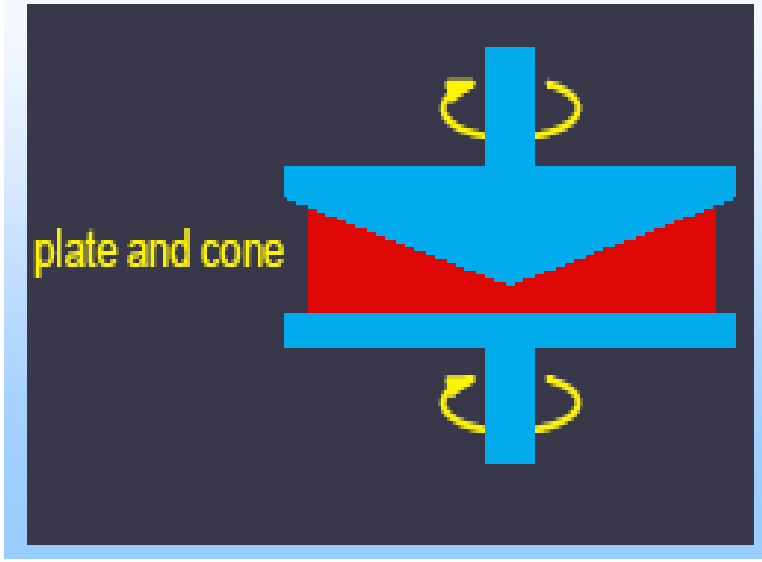
Science of the deformations: it studies the relationship between strain ε and stress τ.

A real fluid is usually viscoelastic

$$\tau(t) = \varepsilon_0 \cdot G'(\omega) \cdot \sin(\omega \cdot t) + \varepsilon_0 \cdot G''(\omega) \cdot \cos(\omega \cdot t)$$

Elastic modulus

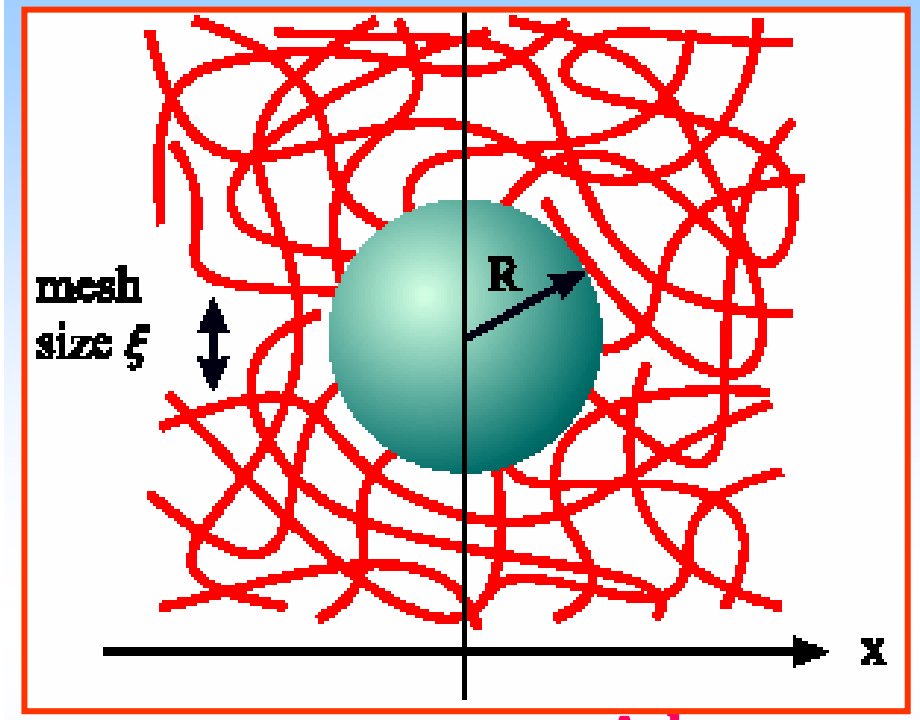
Viscous modulus

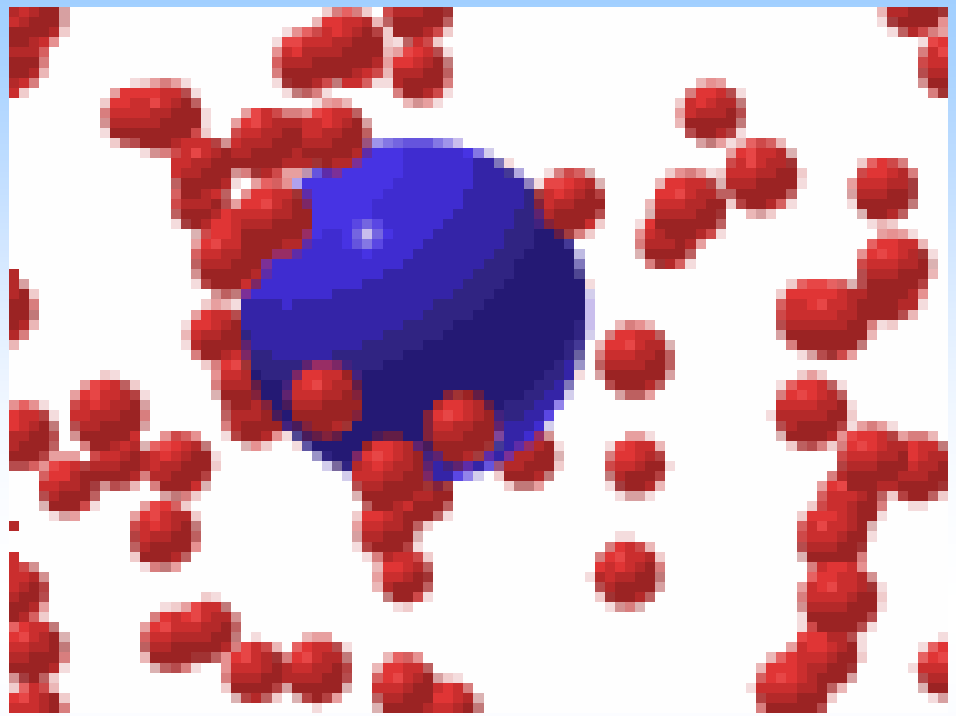


Macro-rheology

- ✓Bulk measurements
- ✓Low frequency range (0-10 Hz)
- ✓Large amount of material (few cc)

Micro-reologia



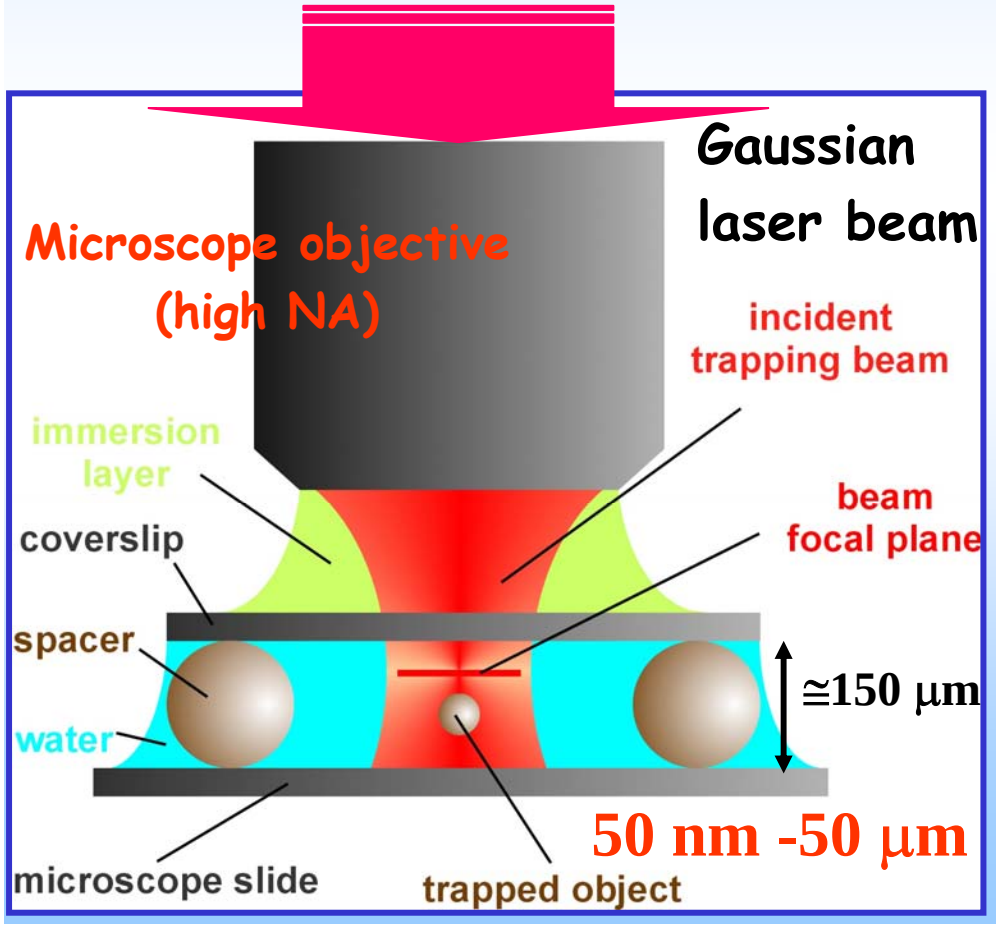


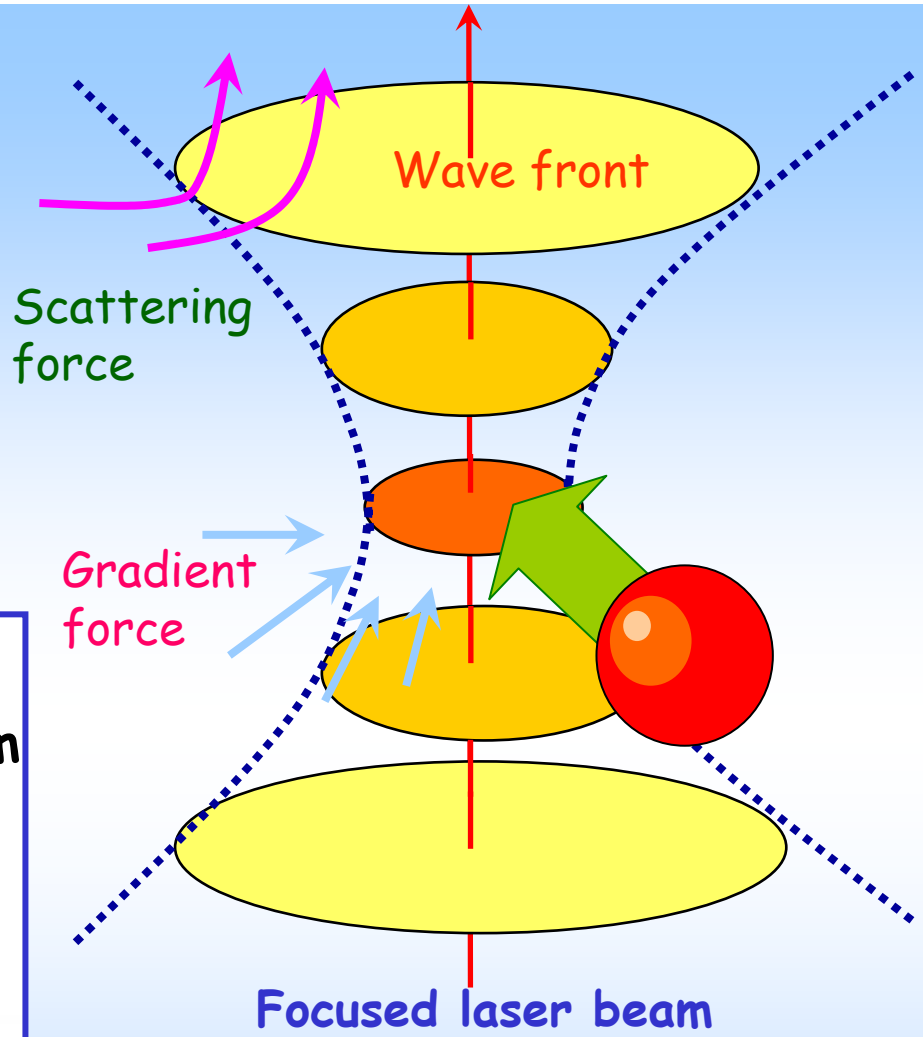
Advantages:

- ✓Microscopic scale samples
- ✓Micrometric lengths
- ✓Study inhomogeneities in complex fluids
- ✓Study small samples (biological materials)
- ✓High frequencies (0-1 MHz)
- ✓Probe scale dependent materials properties
- ✓Phase transitions (sol-gel)
- ✓Anysotropic fluids

Effetti meccanici della luce

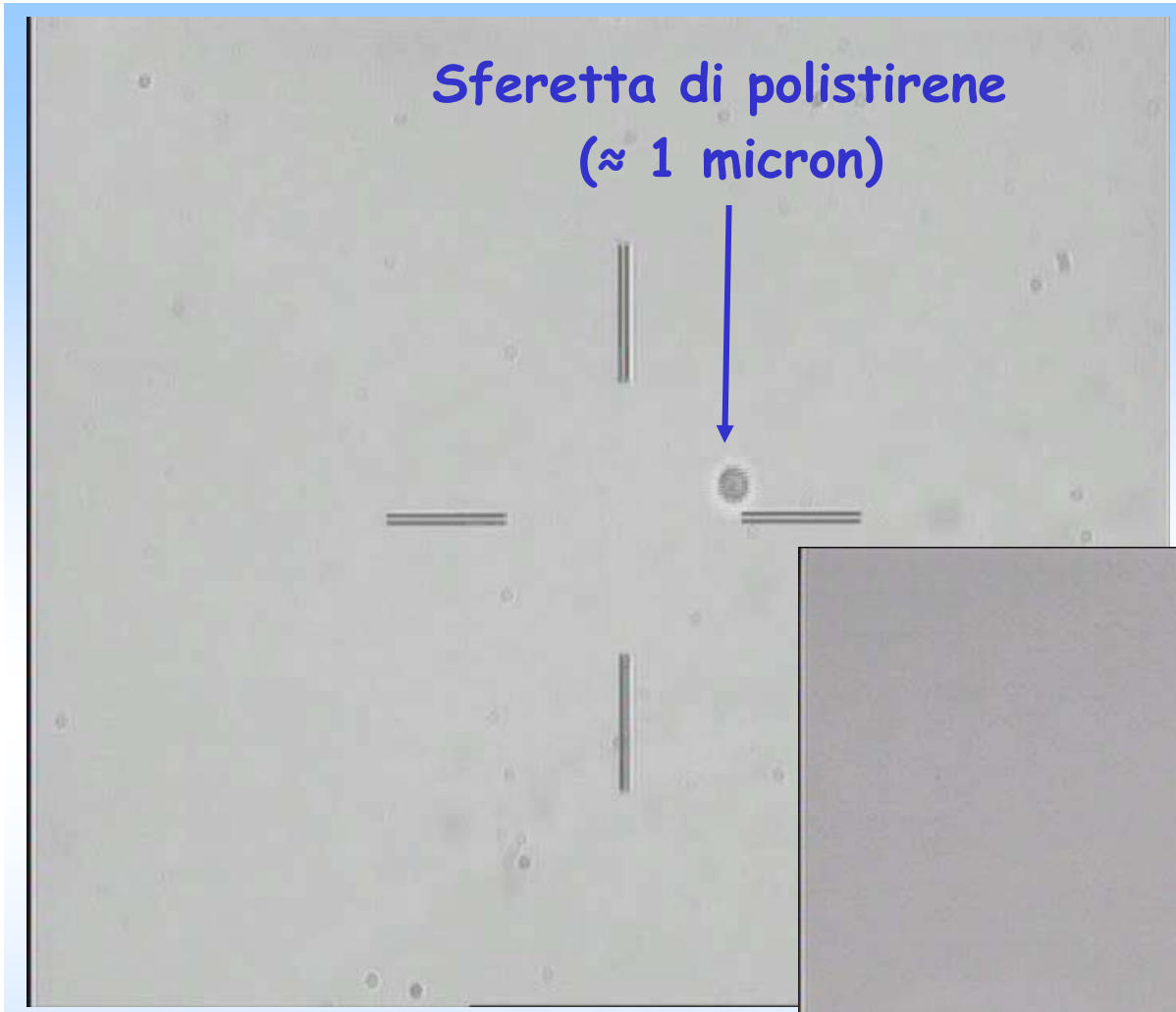
✓Johannes Kepler (1571)

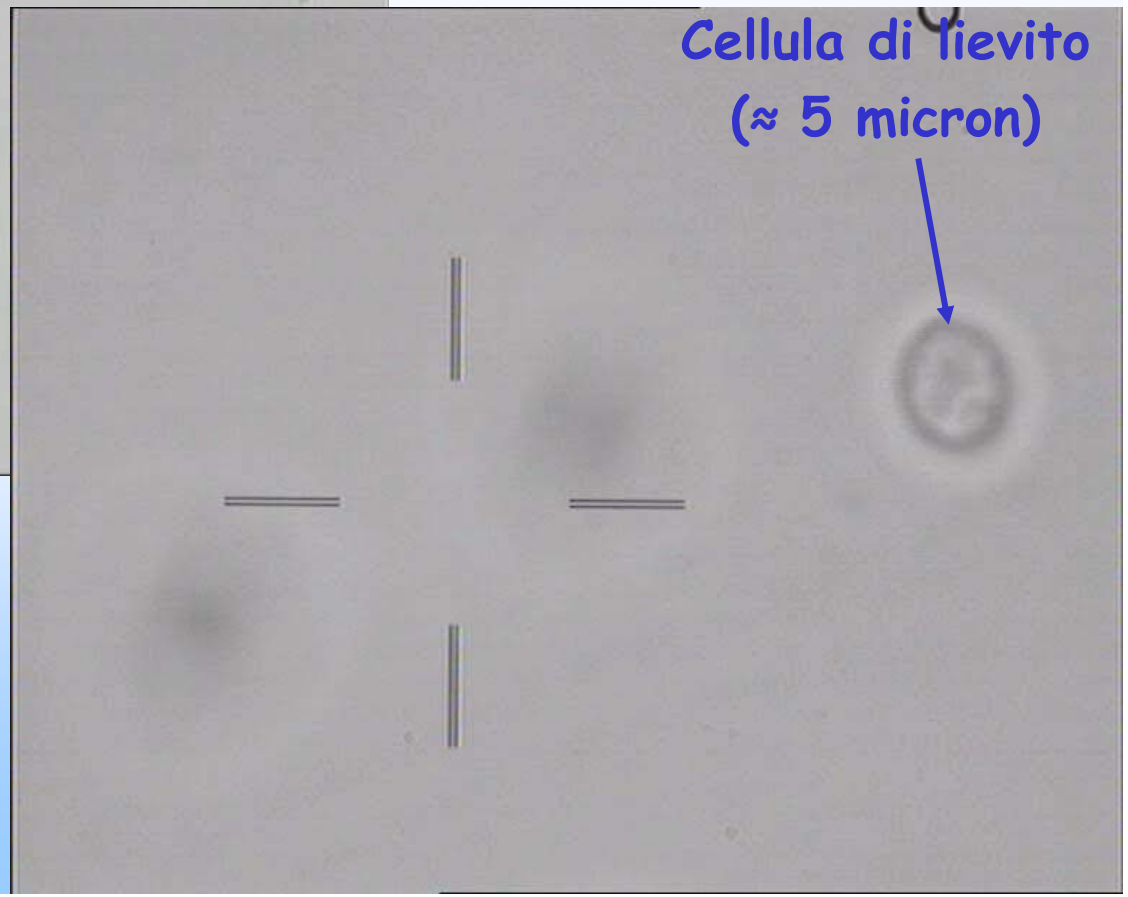


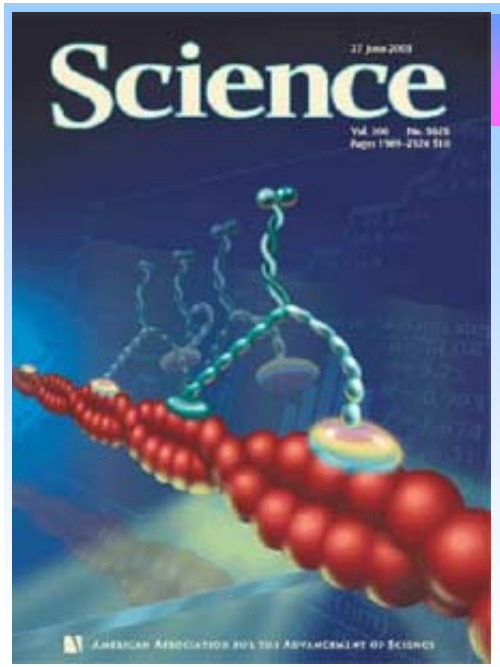


$$F_i = -k_i r_i \quad i = x, y, z$$

force: 10fm – 200 pN

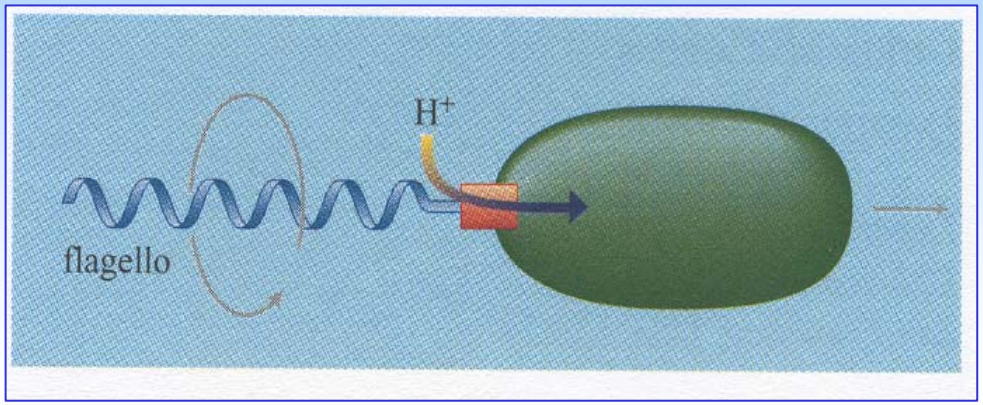

Sferetta di polistirene
(≈ 1 micron)


Cellula di lievito
(≈ 5 micron)

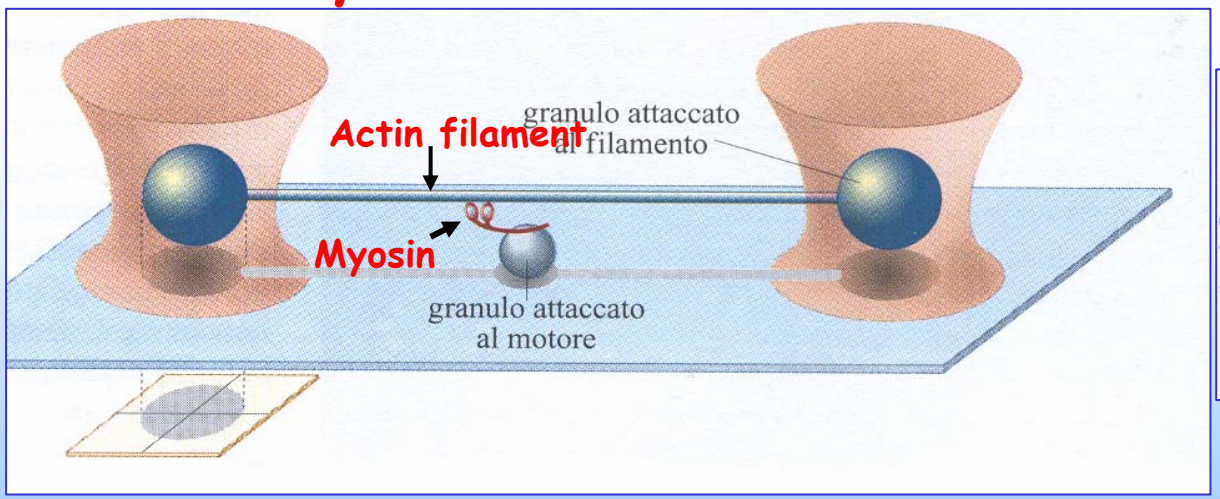


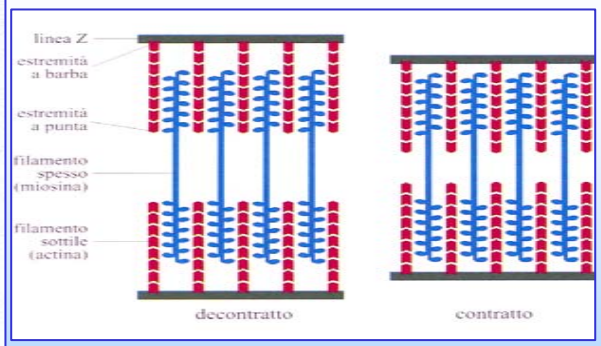
Molecular motors

flagella

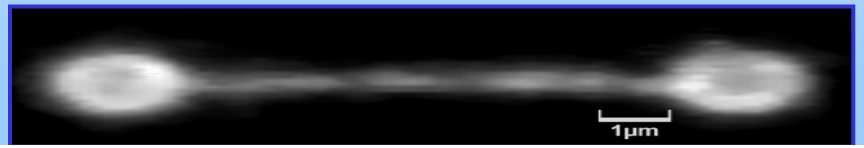


Actin – Myosin motor

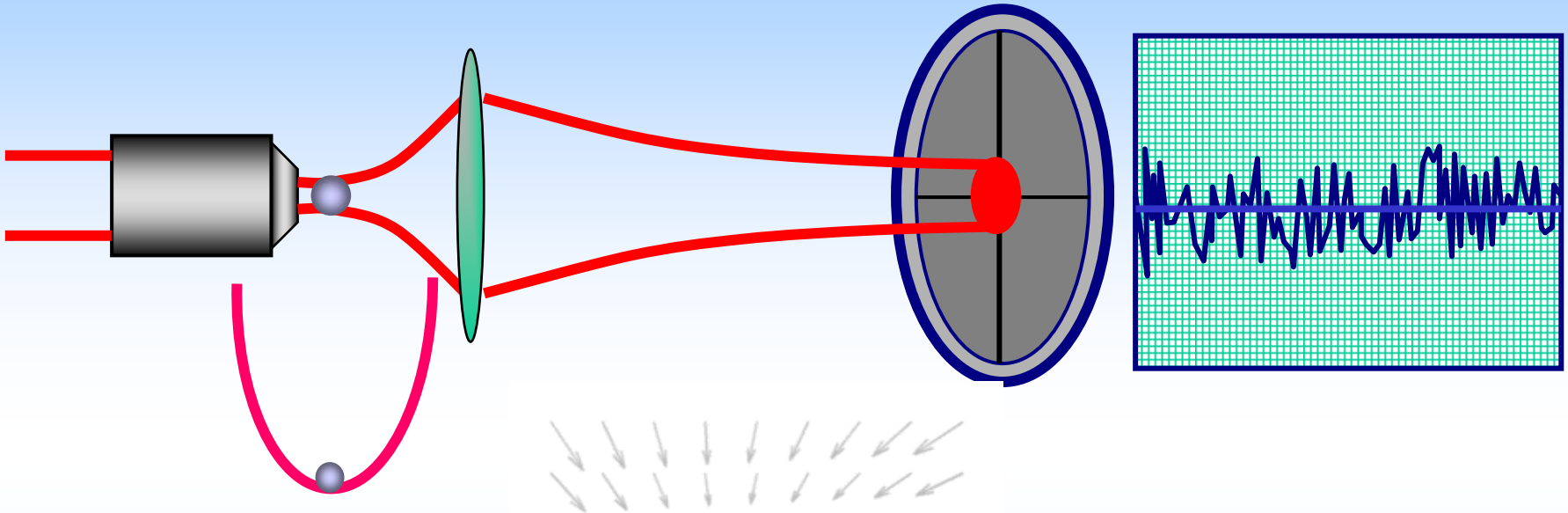


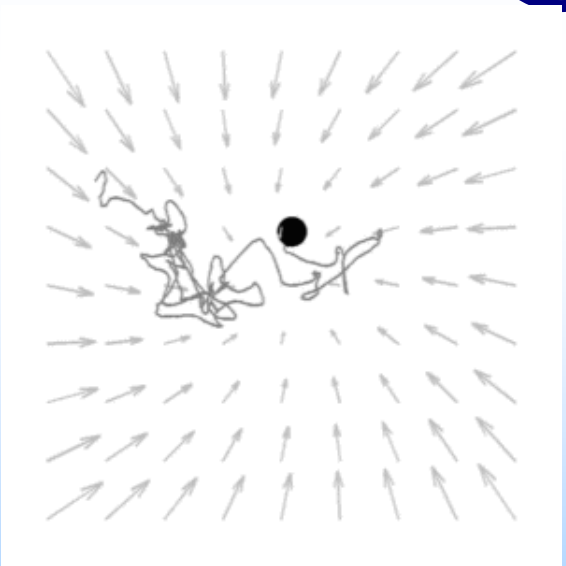


Mussle unit: sarcomer

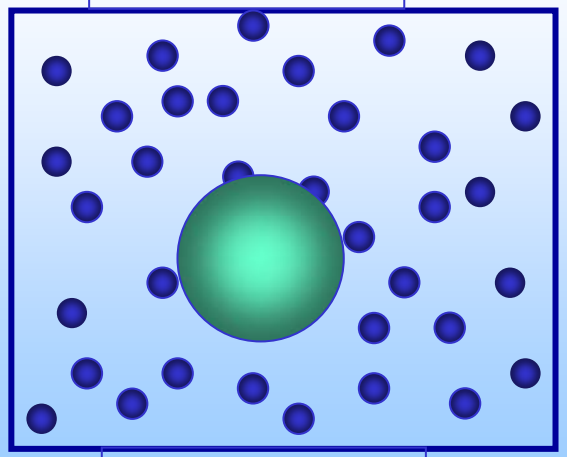


Thermal analysis (Brownian motion)



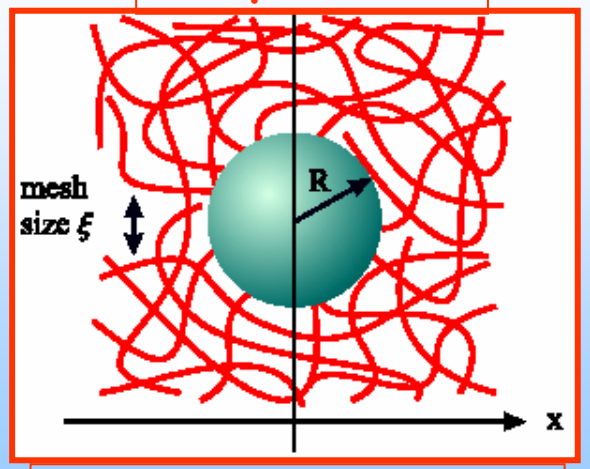


Simple fluid



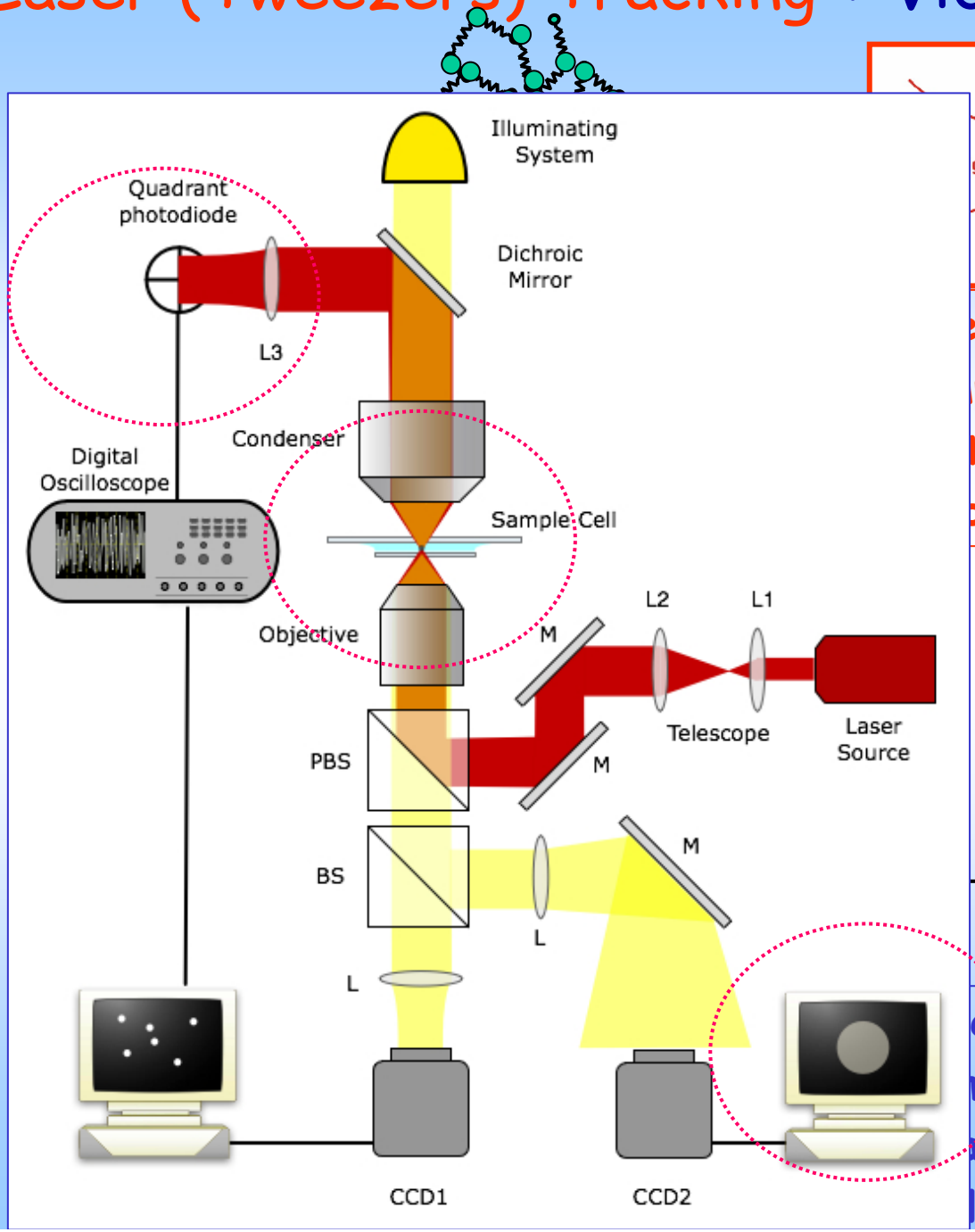
VISCOSITY

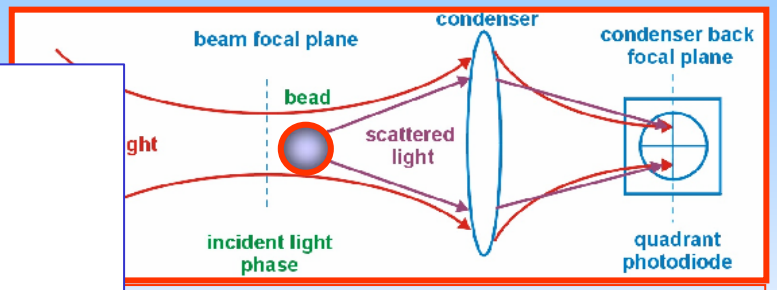
Complex fluid



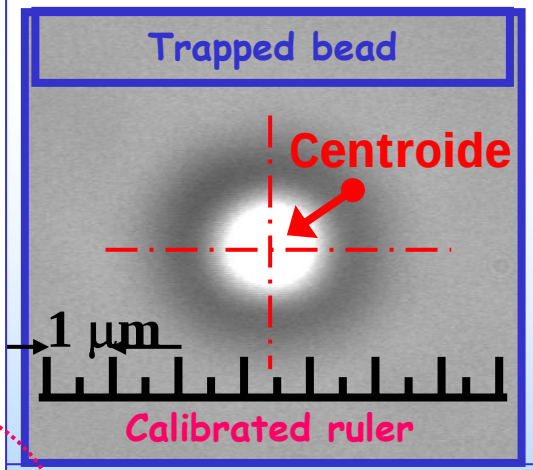
VISCO-ELASTICITY

Laser (Tweezers) Tracking + Video Tracking setup





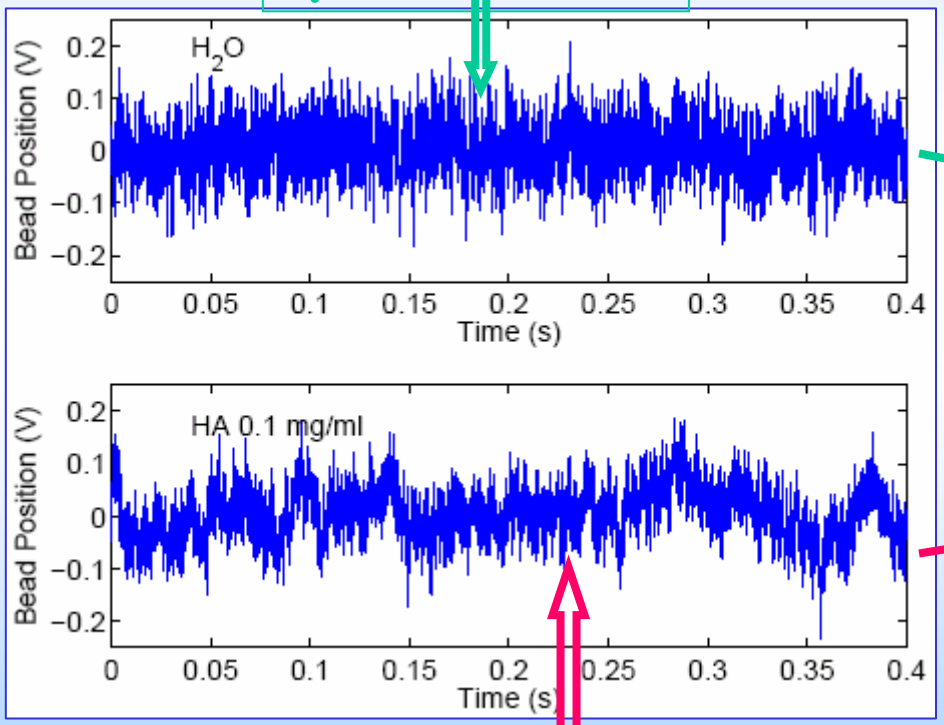
er Tracking (QP):
poral resolution : 100 kHz
tial resolution : 2-3 nm
d-of-view: 200-300 nm

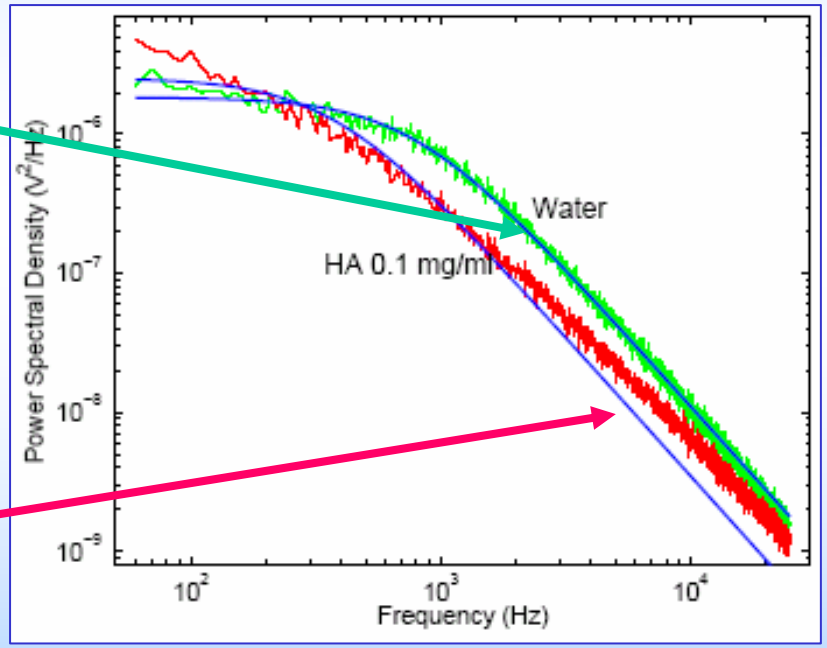


eo Tracking (standard CCD):
mporal resolution : 30 Hz
atial resolution : 6-7 nm
ld-of-view: 50_100 µm

Water-hyaluronic acid solutions

[pure water]

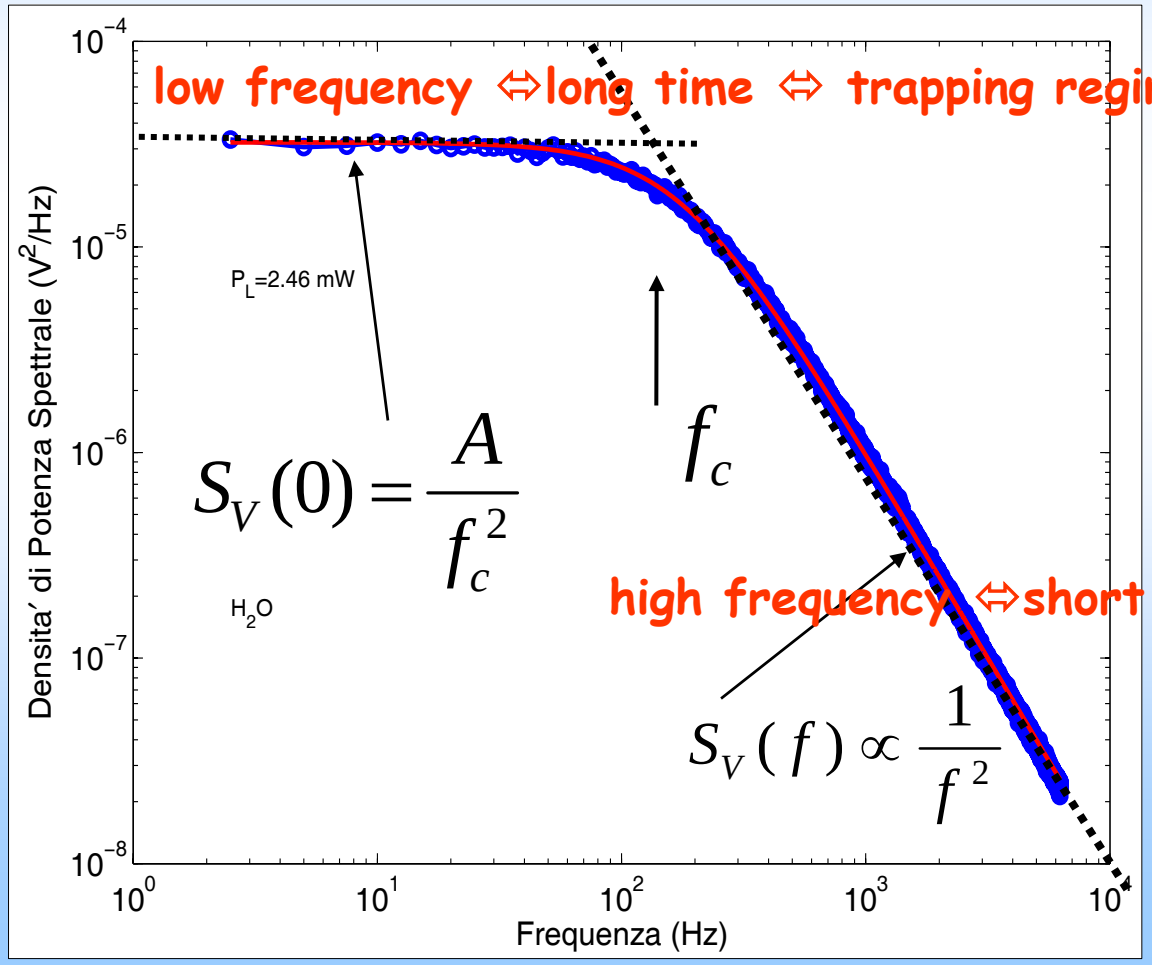




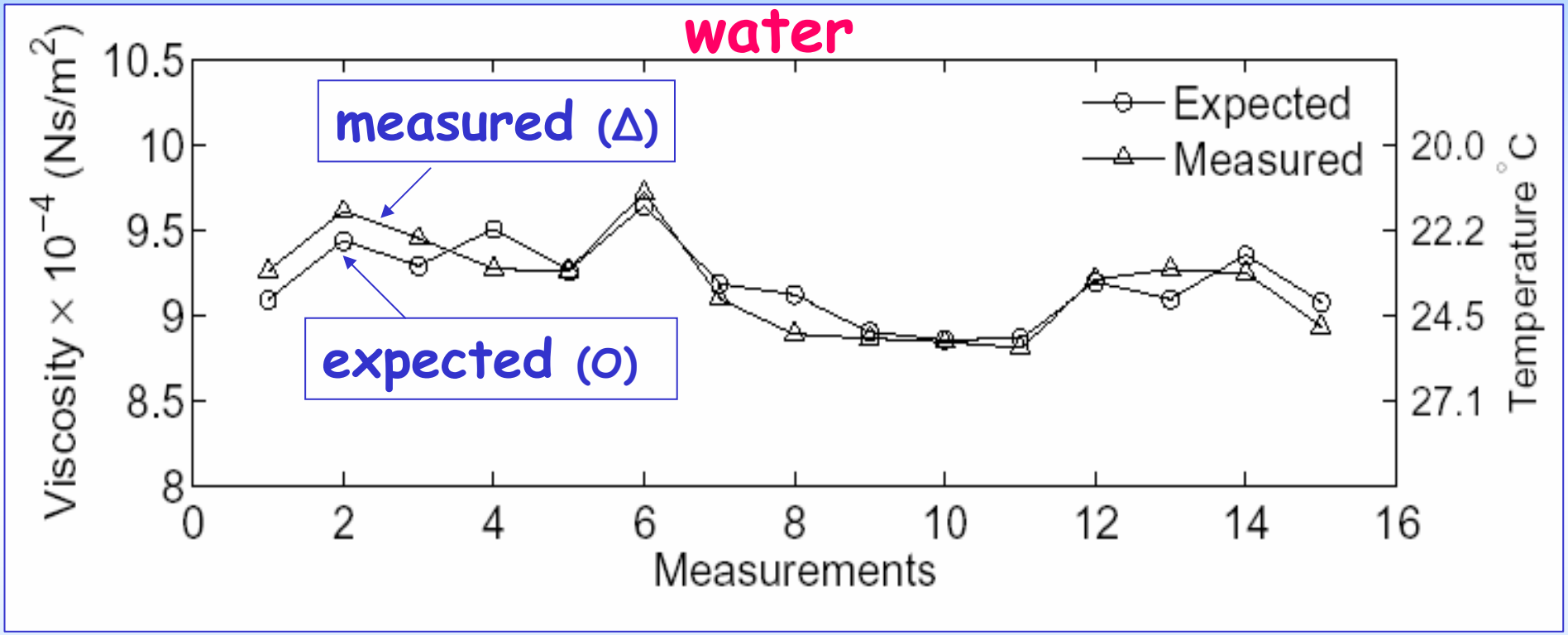
[H_2O-HA 0.1 mg/ml]

Power spectrum method

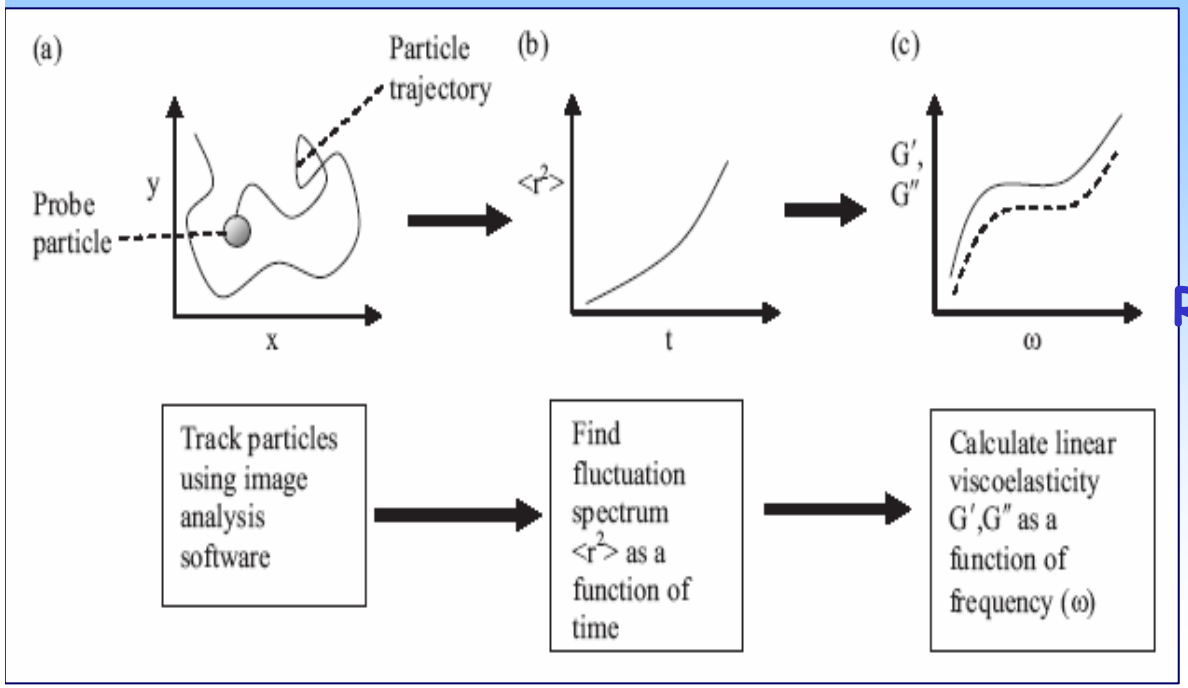
$$S_V(f) = \frac{k_B T}{6\pi\eta a\beta^2}\frac{1}{f_c^2 + f^2}$$



after calibration……. local viscosity



G.Pesce et al. Rev. Sc. Instr. 76, 115105 (2005)



$$stress = G(\omega) \times strain$$

$$G(\omega) = G'(\omega) + iG''(\omega)$$

Response of a trapped bead:

$$x(\omega) = \alpha(\omega) f(\omega)$$

- **Fluctuation-dissipation theorem:**

$$\alpha''(\omega) = \frac{\omega}{2k_B T} \langle x^2(\omega) \rangle$$

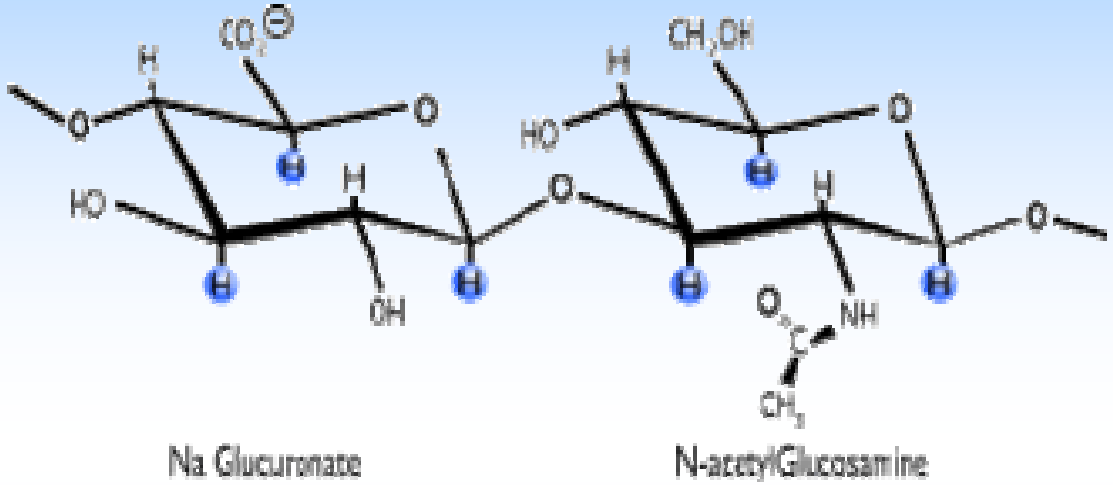
- **Kramers-Kronig:**

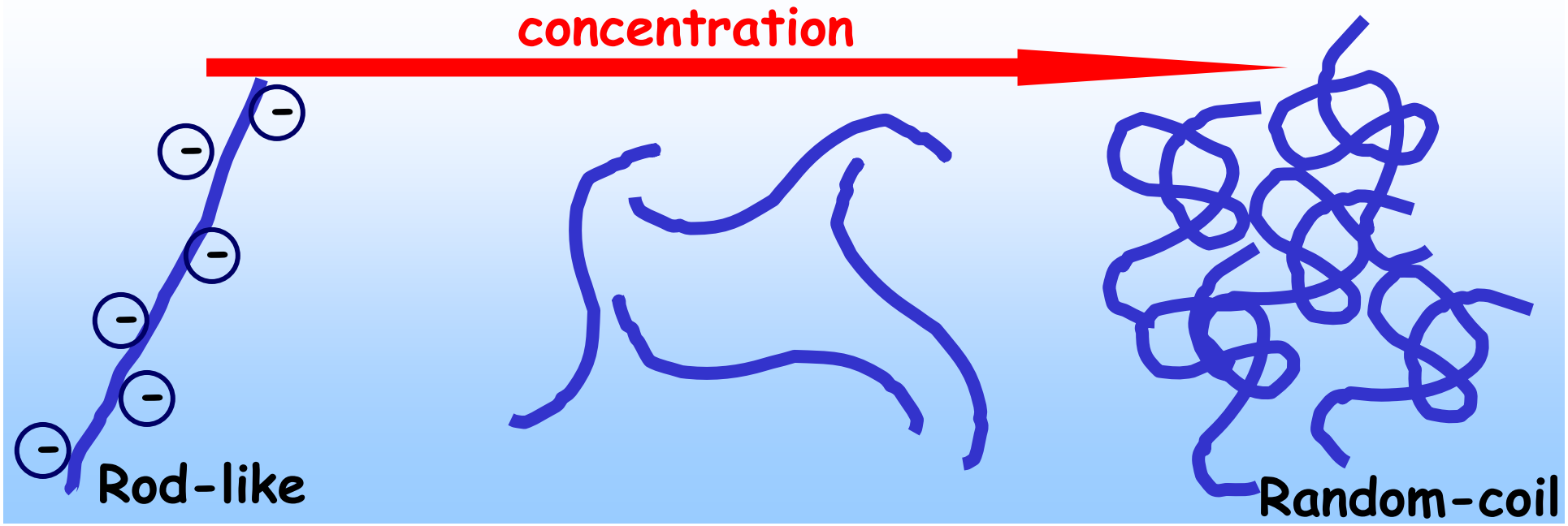
$$\alpha'(\omega) = \frac{2}{\pi} P \int_0^\infty d\zeta \frac{\zeta \alpha''(\zeta)}{\zeta^2 - \omega^2}$$

- **Generalized Stokes-Einstein:**

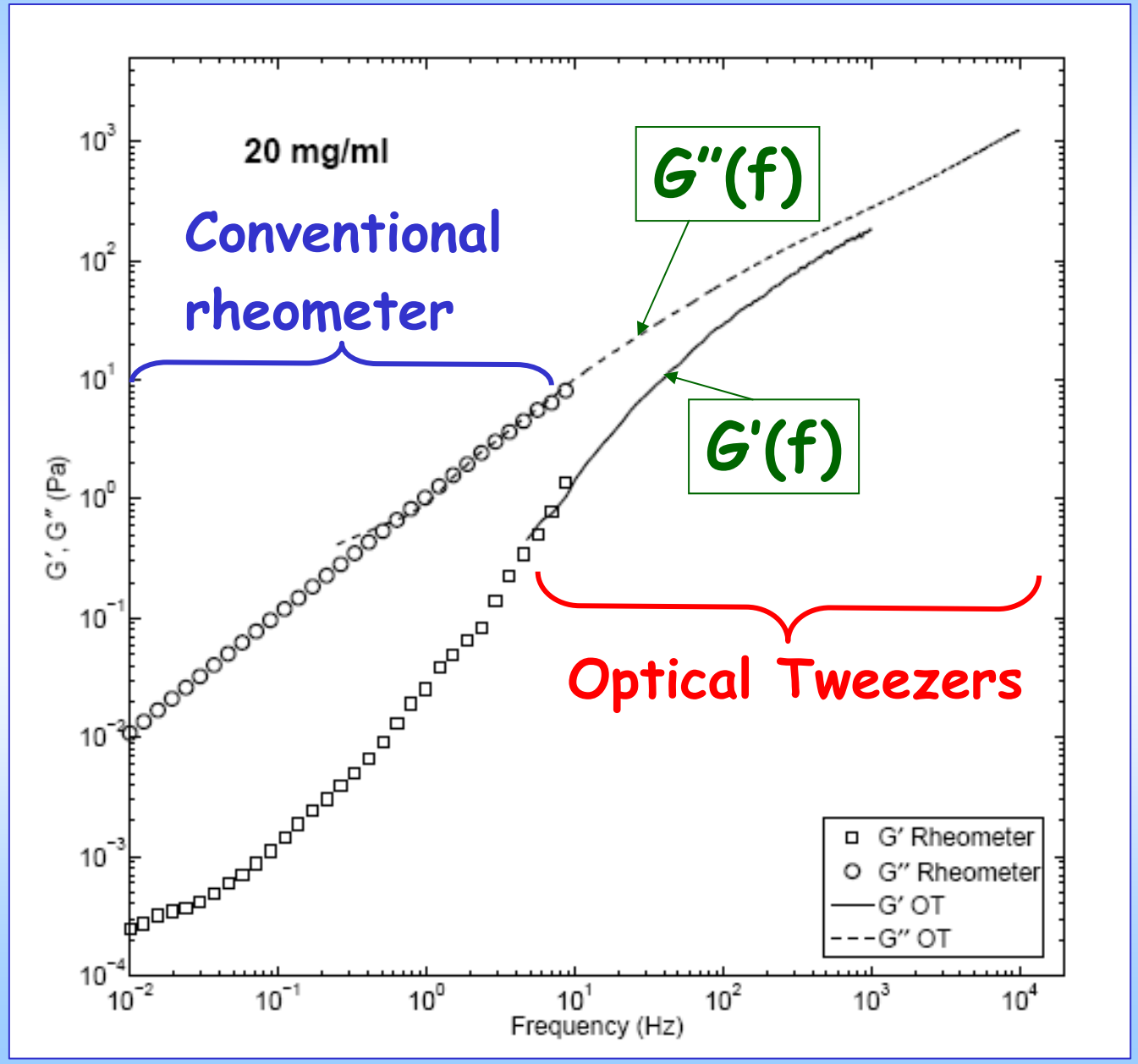
$$\alpha(\omega) = \frac{1}{6\pi G(\omega) a}$$

Polyelectrolyte in salt-free solutions:
Hyaluronic Acid (HA) (160 kDalton)



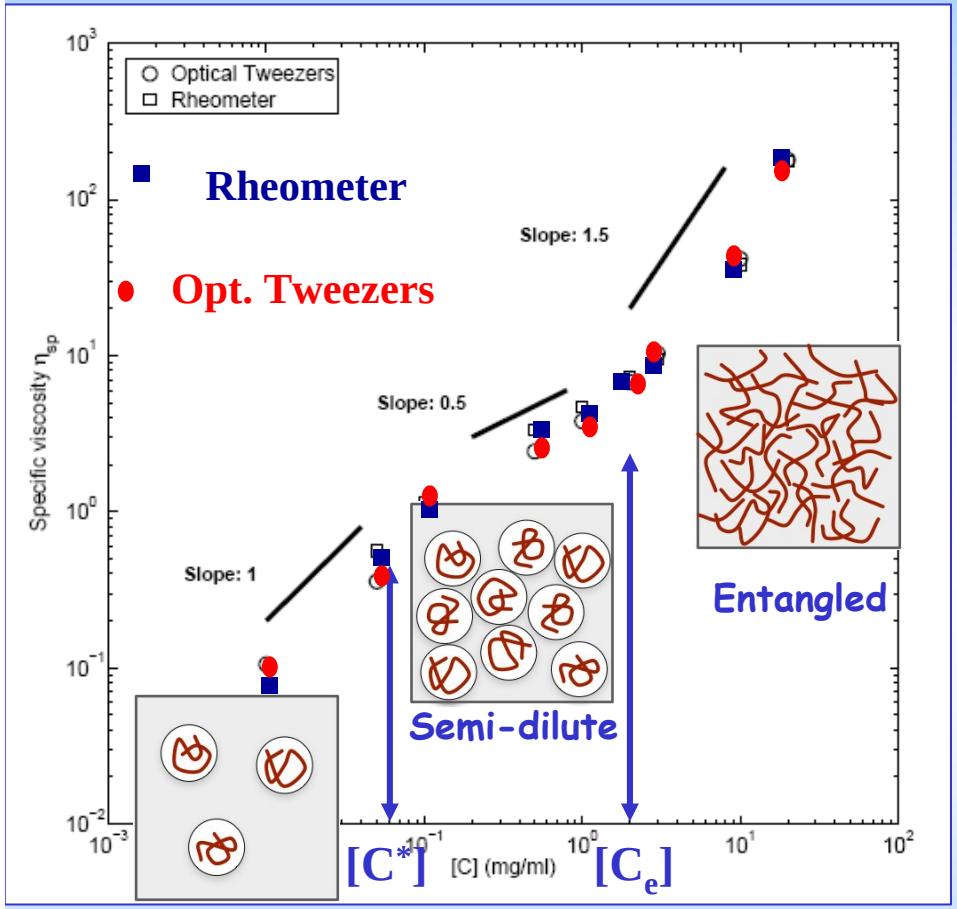


Comparison between bulk and local measurements

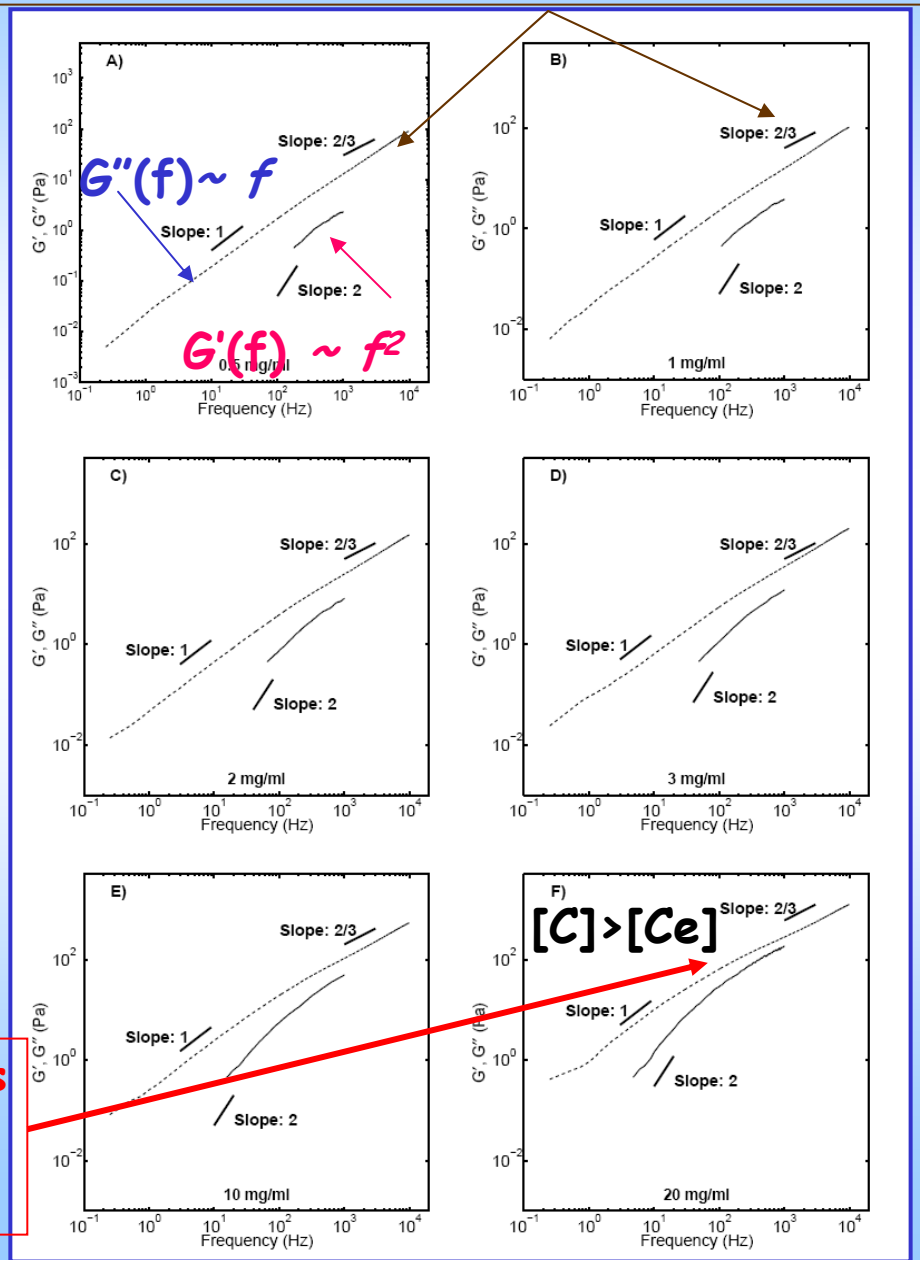


Good agreement with power laws of polyelectrolytes models

$G'(f),\ G''(f) \sim f^{2/3}$ (high frequencies)

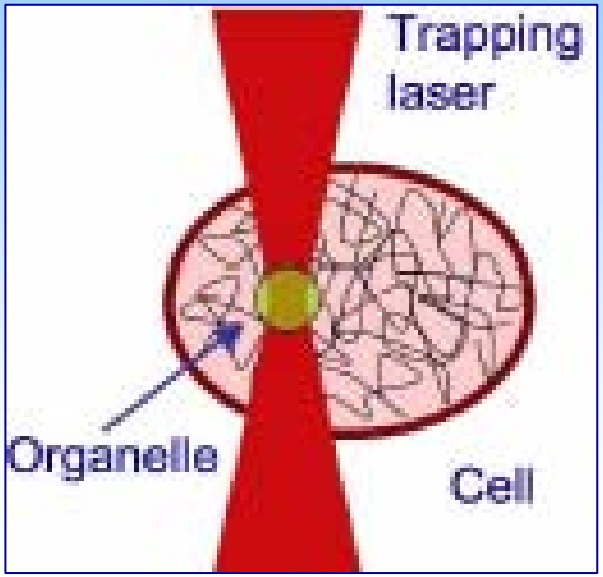


Dilute regime



No crossing! No permanent entanglements is formed due to the low entanglements number ($n = 2.5$)

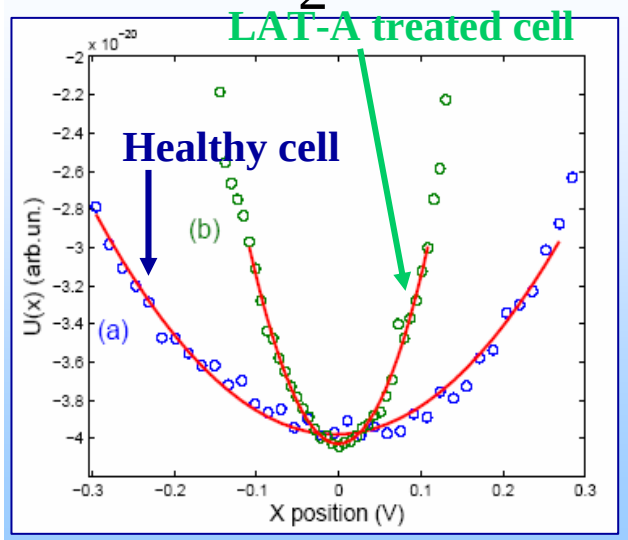
Viscosity measurements in yeast cells (*Saccharomyces cerevisiae*)

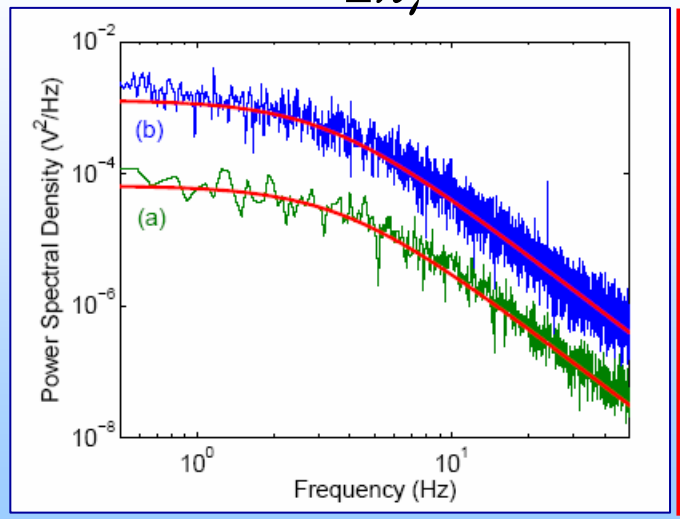


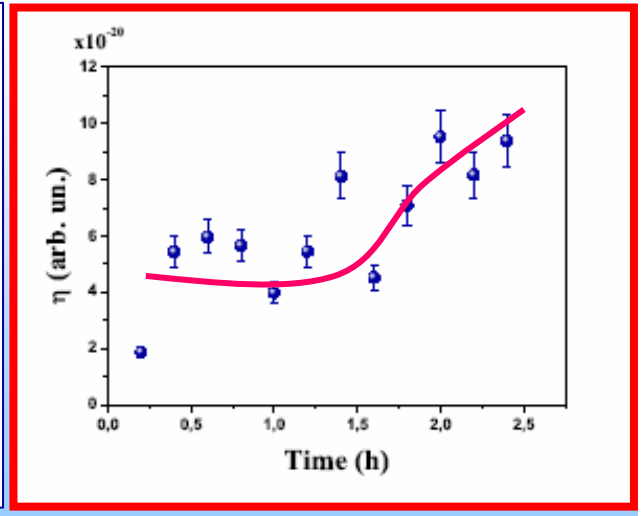
$$U(x) = \frac{1}{2} k \beta^2 x^2$$

$$f_c = \frac{k}{2\pi\gamma}$$

$$R = \frac{k\beta^2}{f_c} \propto \eta$$



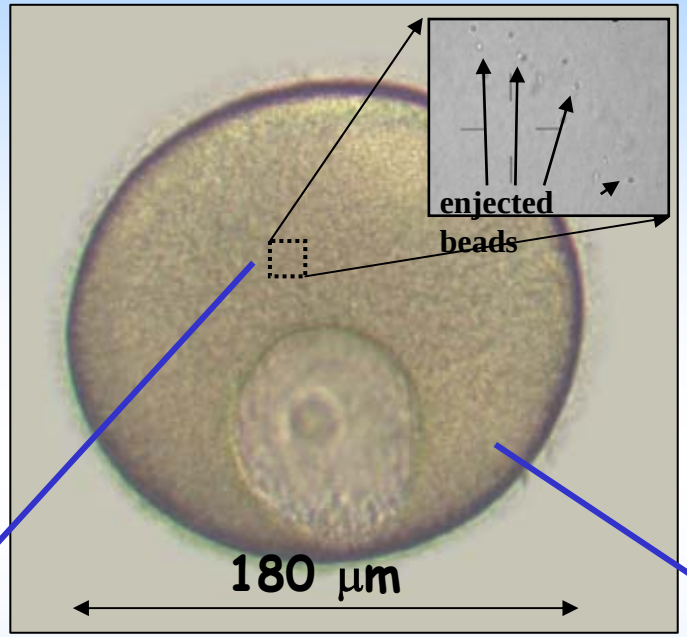


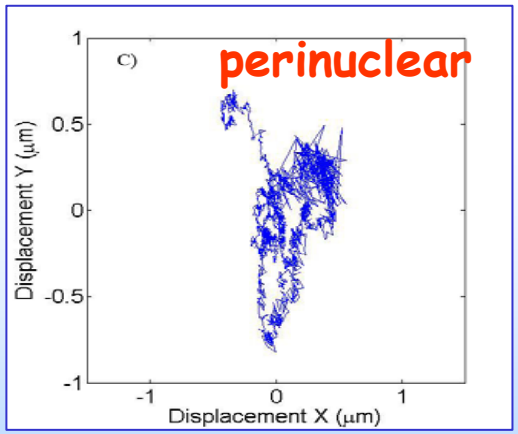


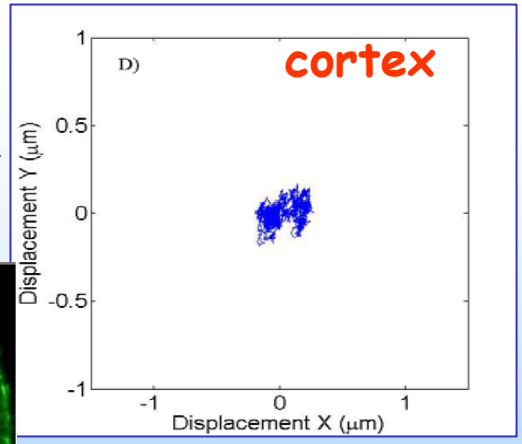
- AC De Luca, G.Volpe, A. Morales Drets,MI Geli, G. Pesce, G. Rusciano, A.Sasso, D. Petrov: Opt.Express, 2007

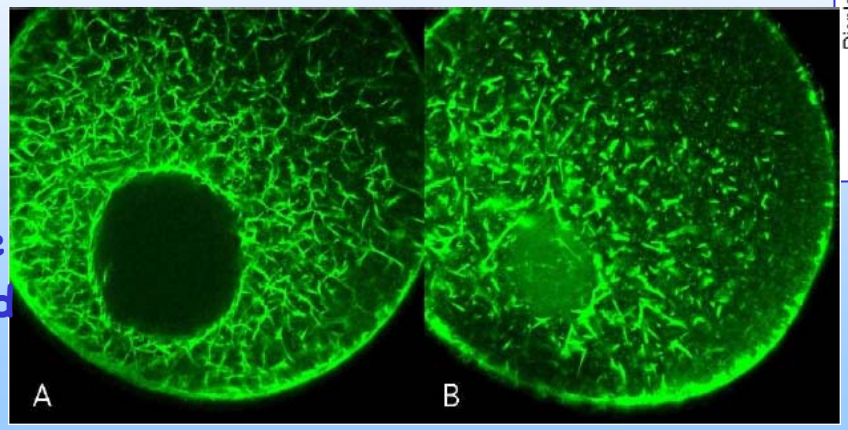
Micro-enjection of polystyrene beads in

Astropecten auranciacus oocytes

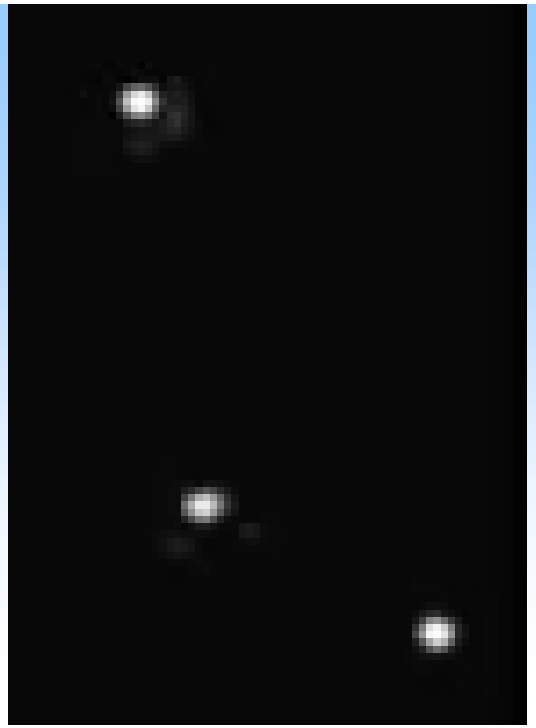


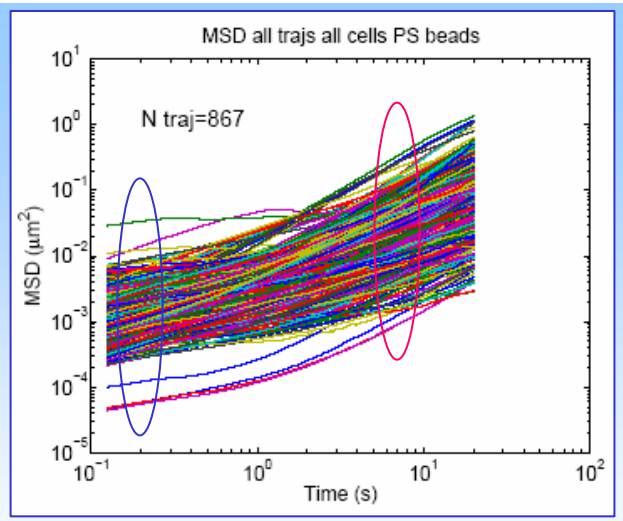


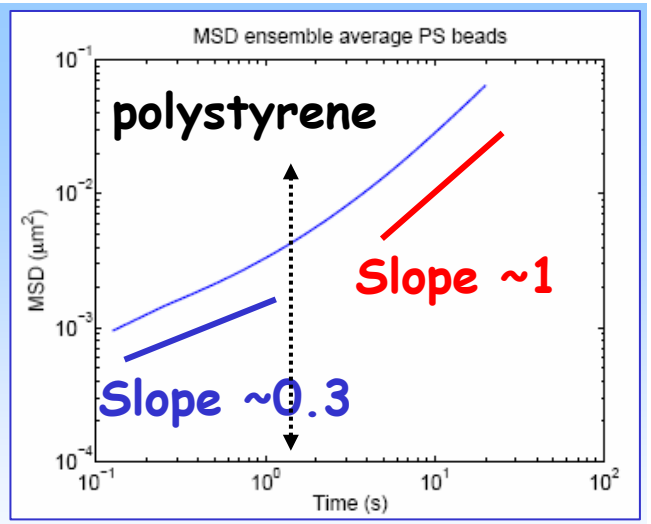




confocal microscopic image of F-actin network stained with Alexa Fluor488 Phalloidin



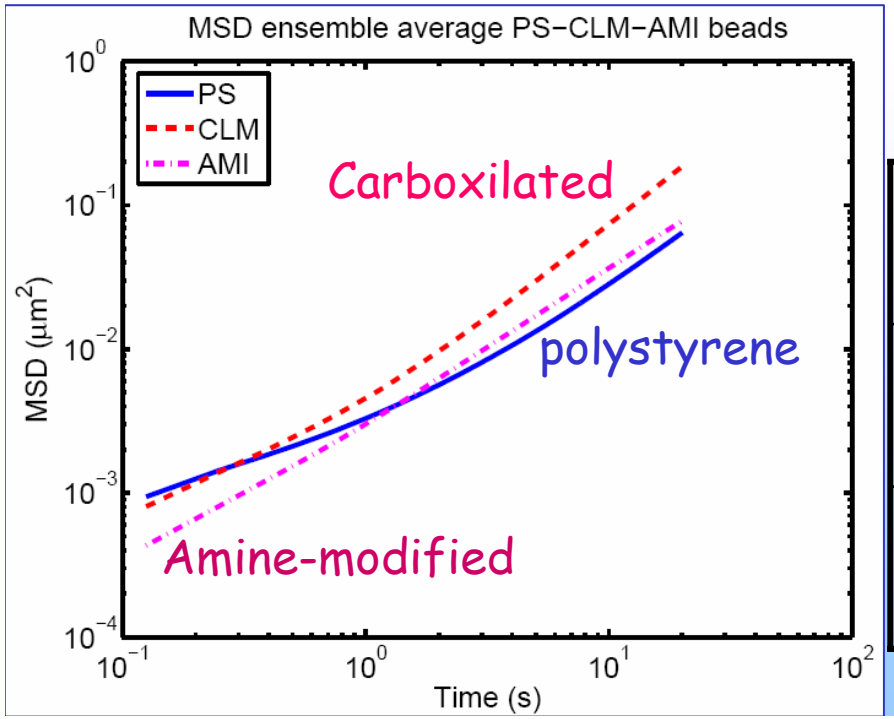




$$\langle r^2(\tau)\rangle = 4D\tau^{\alpha}$$

$$\alpha = \alpha(\tau)$$

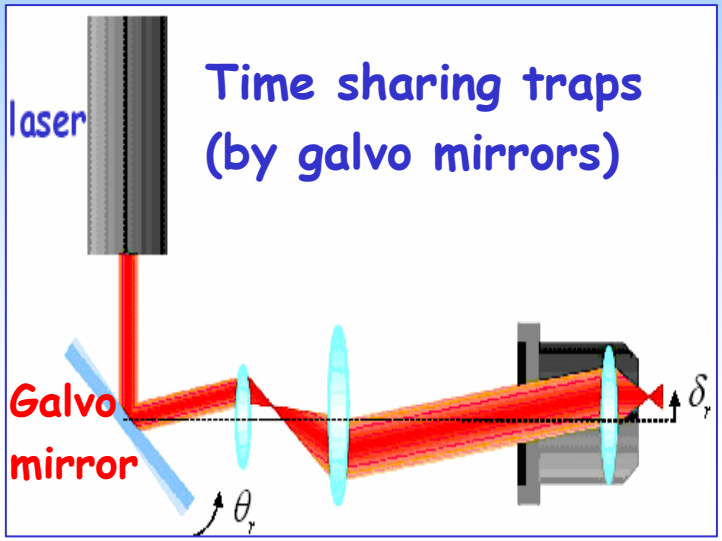
$\alpha = 1$	Stokes - Einstein diffusion in pure viscous fluid
$\alpha < 1$	Sub - diffusive motion (viscoelastic fluid)
$\alpha > 1$	Super - diffusive motion (molecular motor)

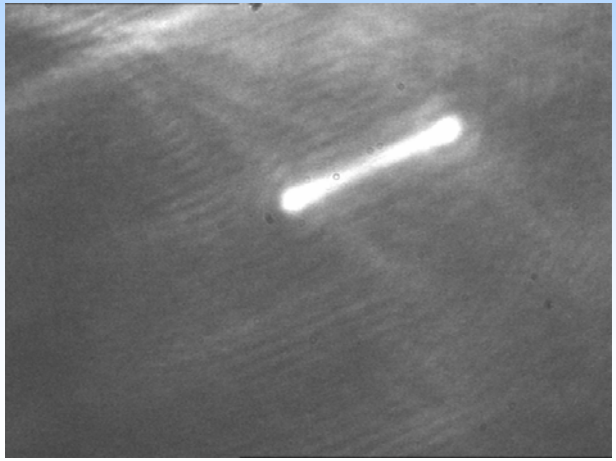


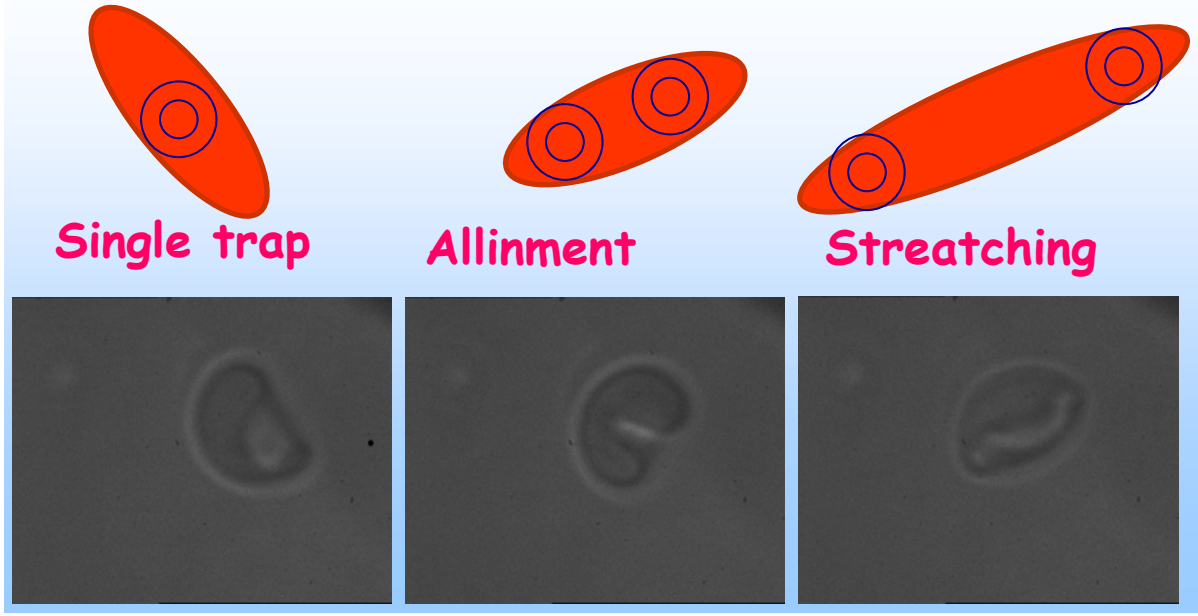
	Polysty.	Carbox.	Amine-m.
D	3.8 10^{-3}μm²/s	7.6 10^{-3}μm²/s	4.6 10^{-3}μm²/s
η	0.85 Poise	0.77 Poise	0.93 Poise

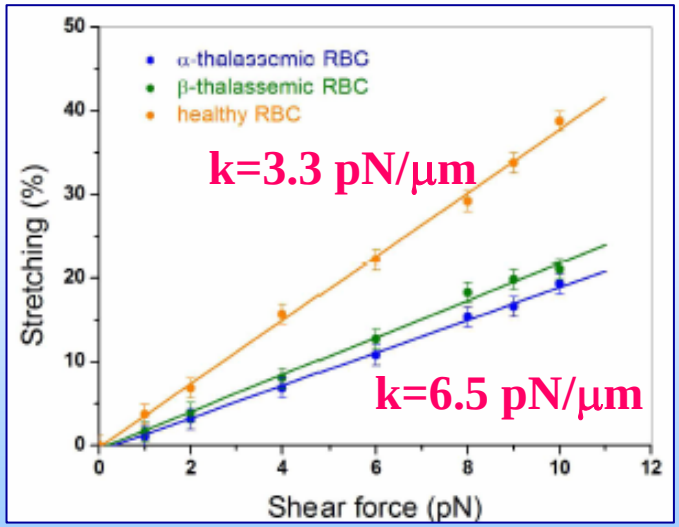
η(water) =0.001 Poise

✓Pure optical Stretcher



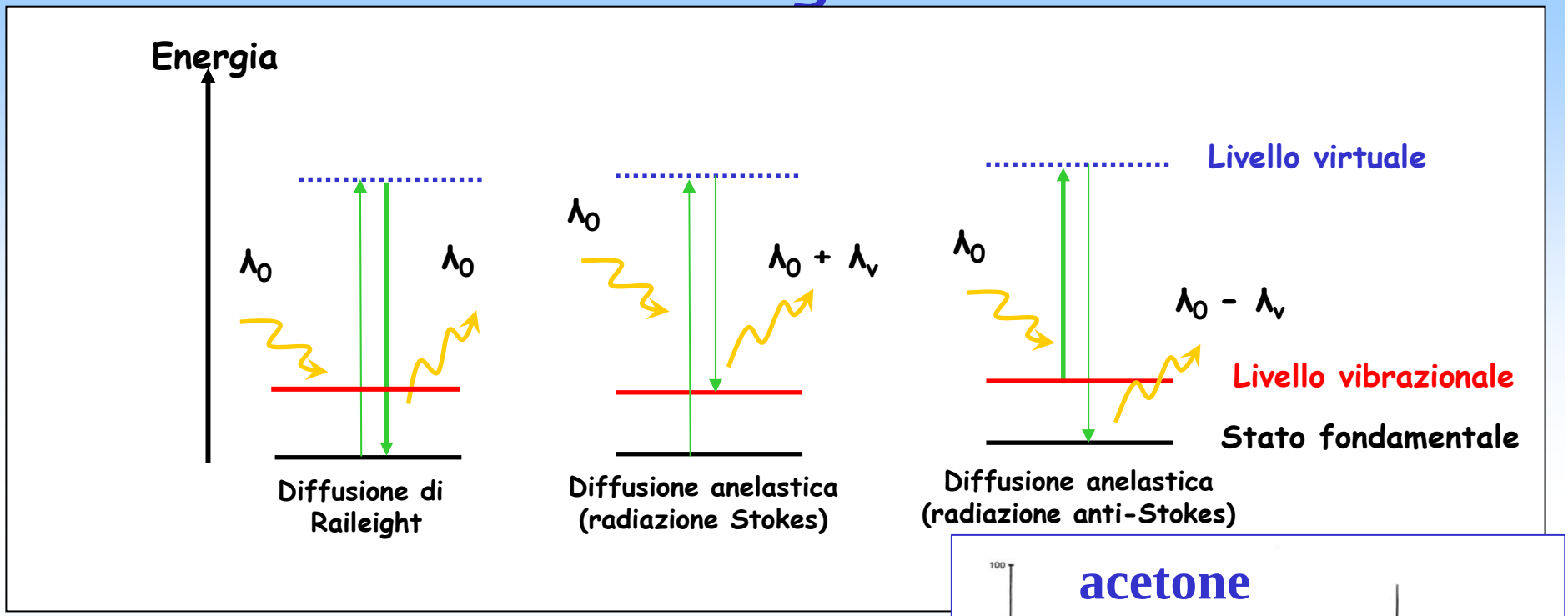


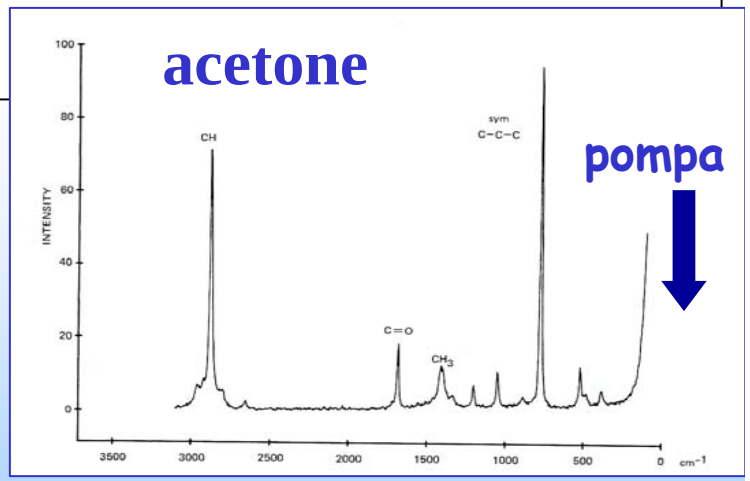




Rusciano et al, Biophy J submitted

Scattering Raman





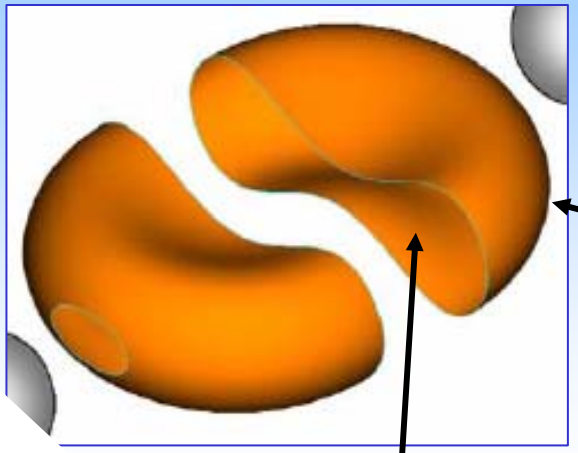
Vantaggi:

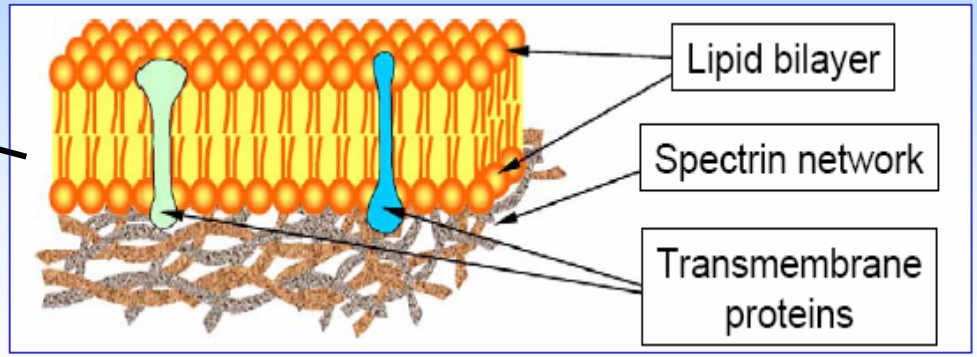
- ✓ Analizza i livelli vibrazionali delle molecole
- ✓ Lo spettro Raman fornisce un'impronta digitale strutturale di una molecola.
- ✓ Può essere applicato in maniera non invasiva in molti campi (ambientale, biologico, medico, farmacologico)

Svantaggi:

- ✓Sezioni d'urto molto piccole (~$10^{-30}/10^{-25}$ cm^2/molecole)
- ✓Segnali Raman sono poco intensi.

Red Blood Cells (erythrocyte)

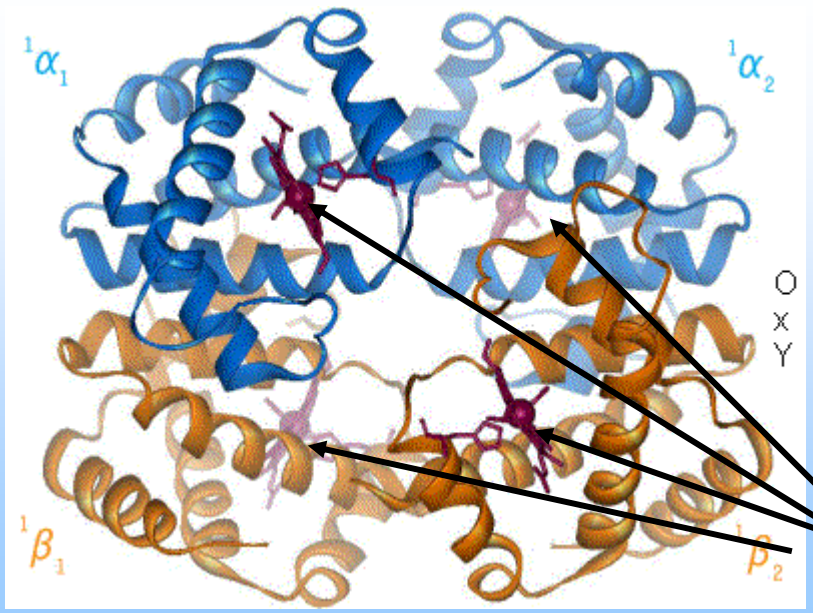


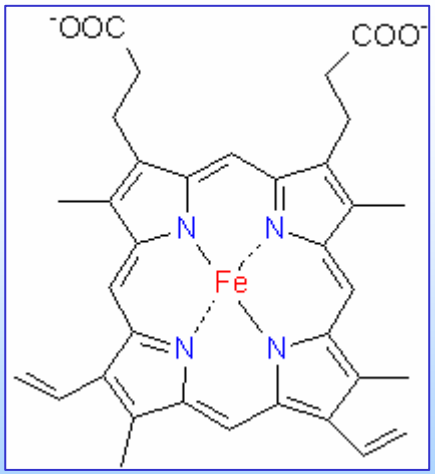


Viscous hemoglobin solution (97% of the RBC dry contenet)

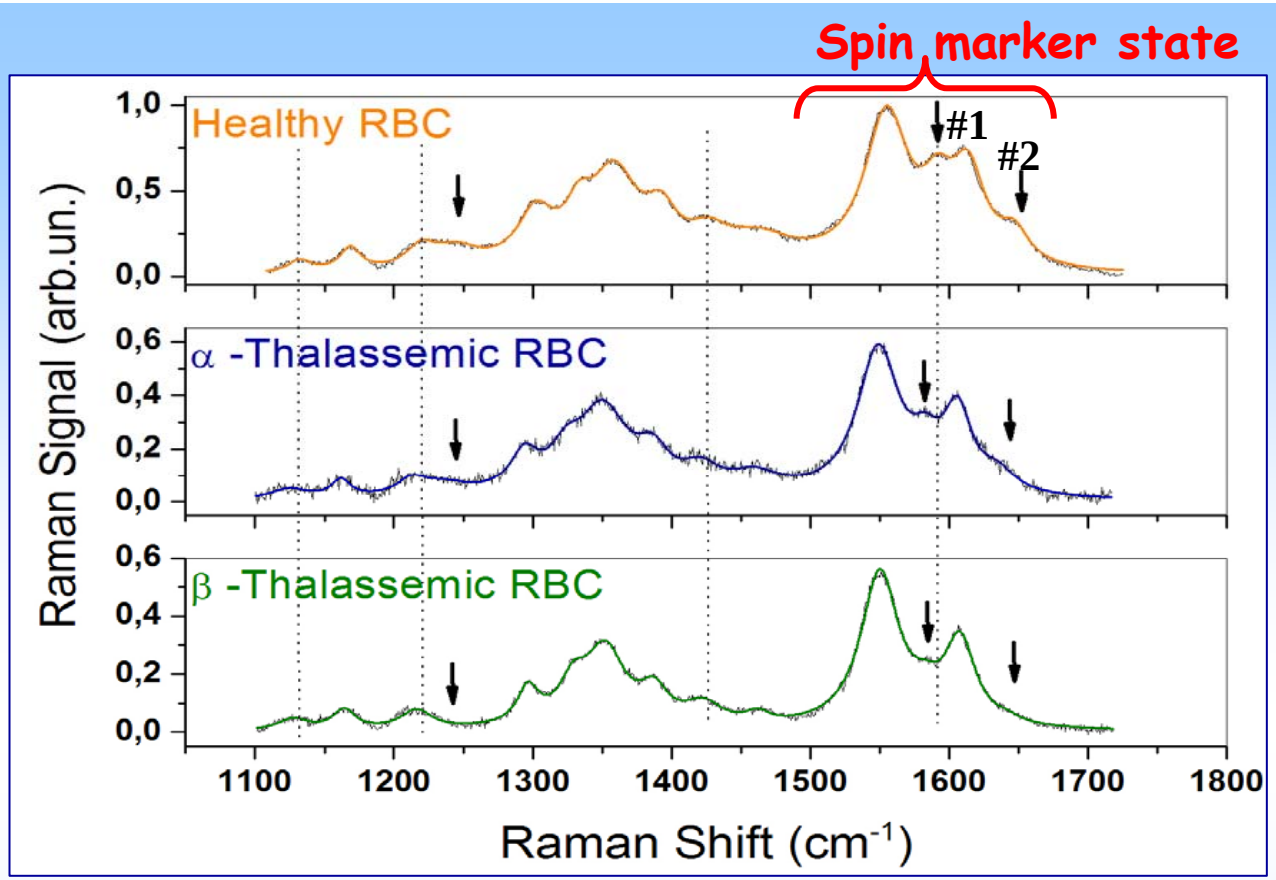
Haemeglobin is a globular metalprotein (tetramer) Formed by 4 subunits:

- **2 α-type**
- **2 β-type**





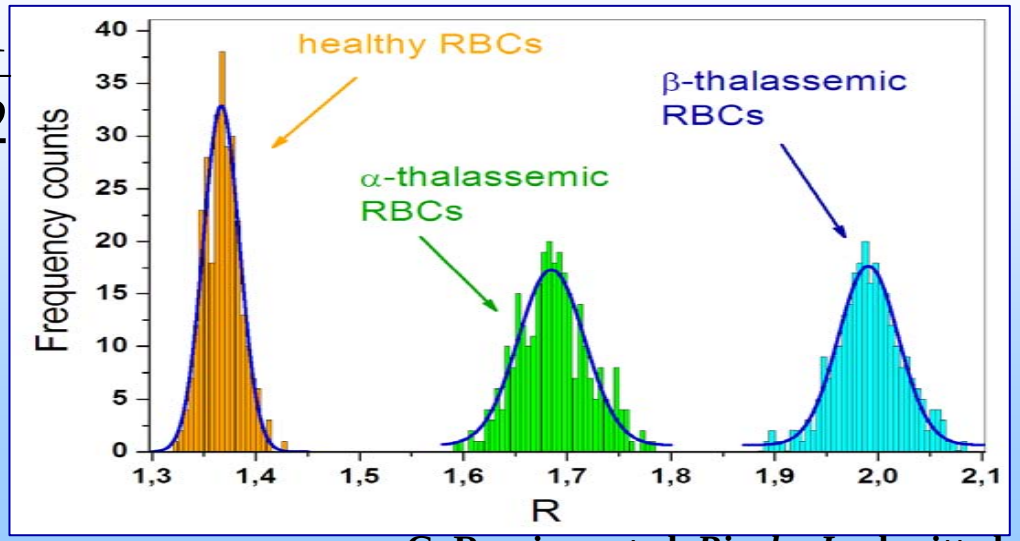
Haeme-group

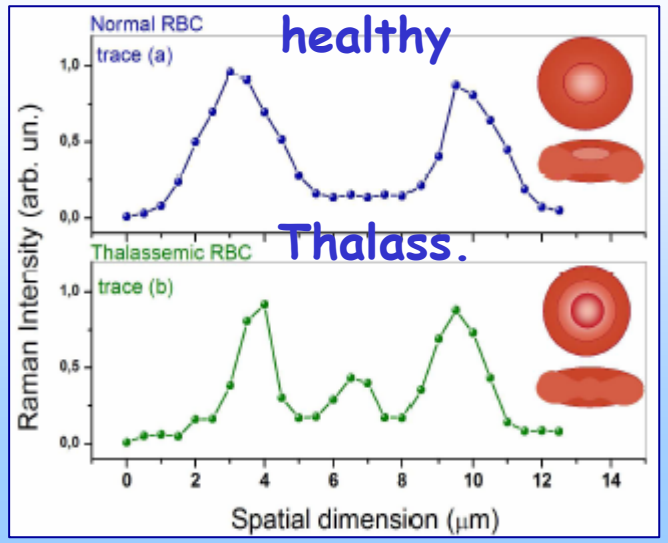


$Fe: \ (S = 1/2)$ Oxy

$Fe: \ (S = 2)$ DeOxy

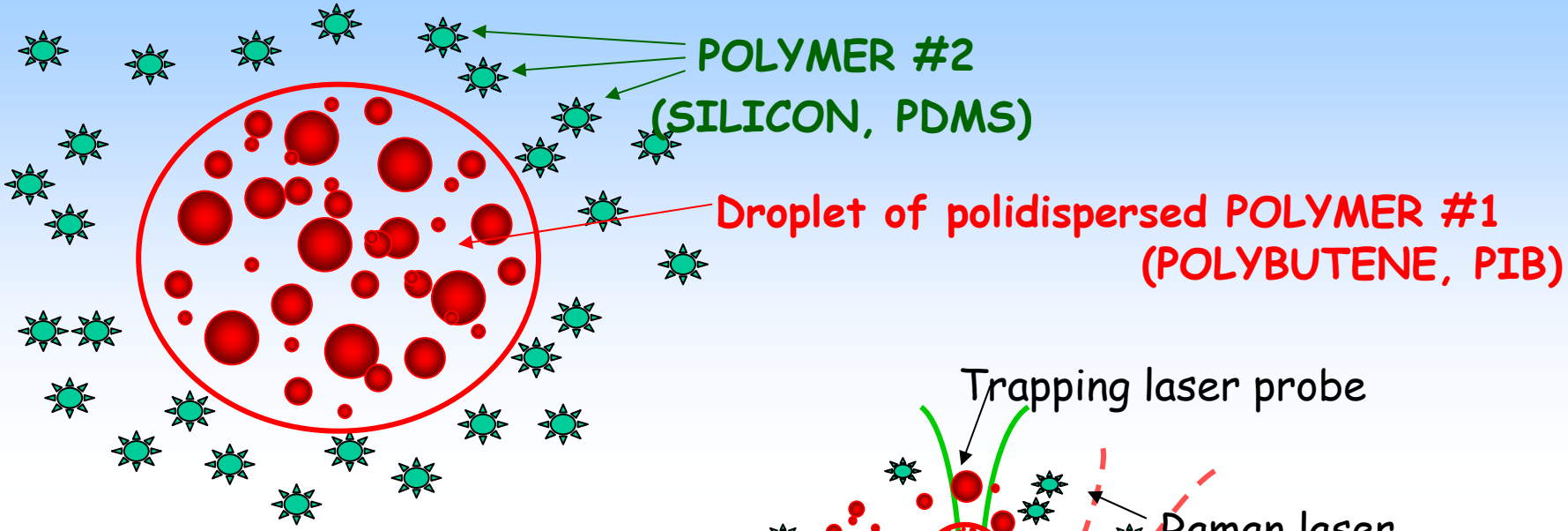
$$R = \frac{\#1}{\#2}$$





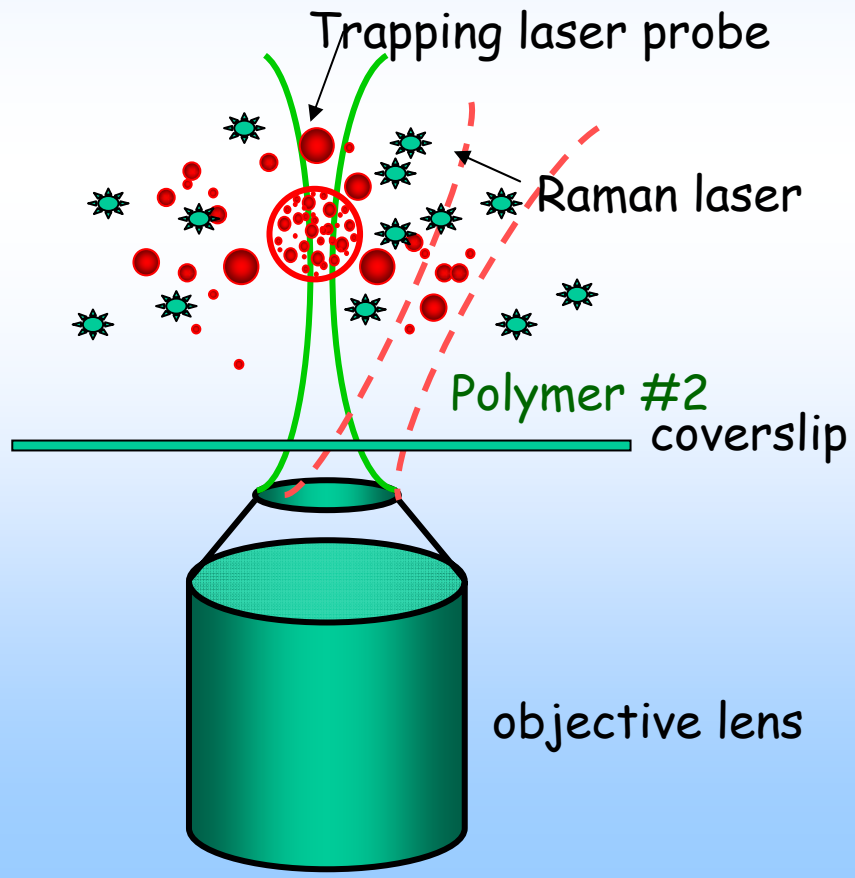
•G. Rusciano et al. *Biophy J* submitted

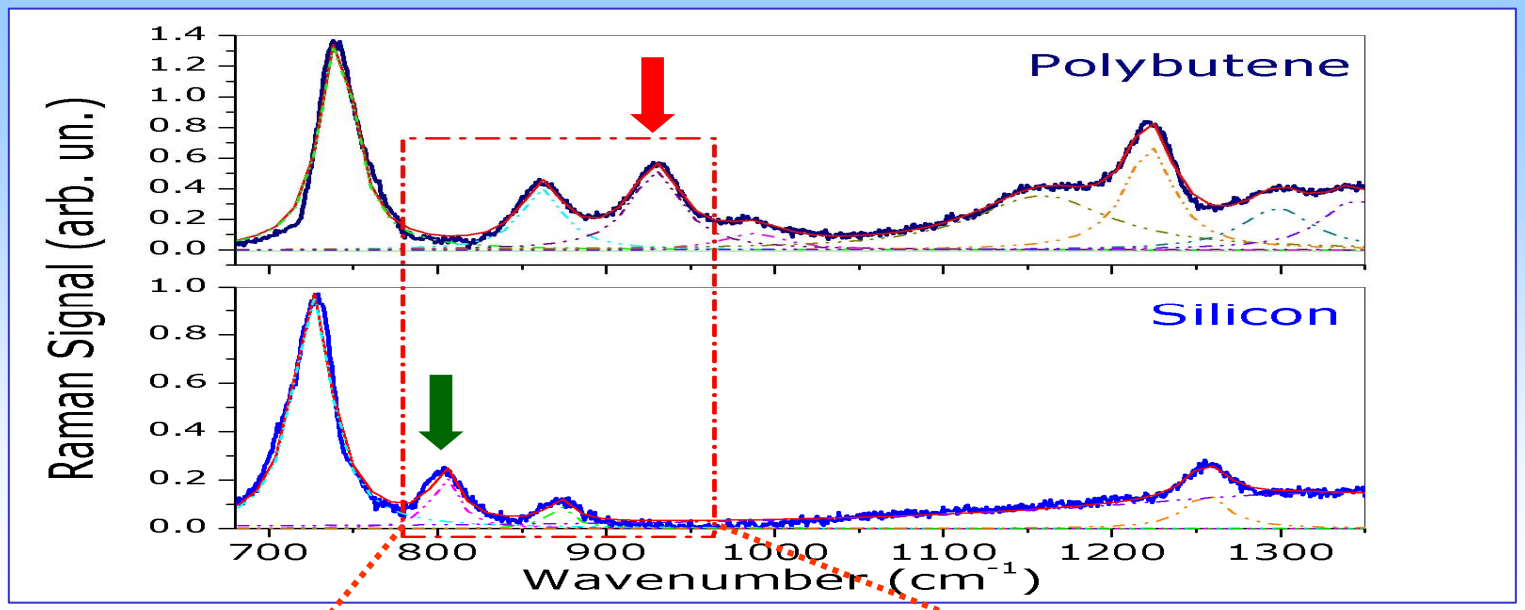
Mutual Diffusion in (immiscible) polymer mixtures

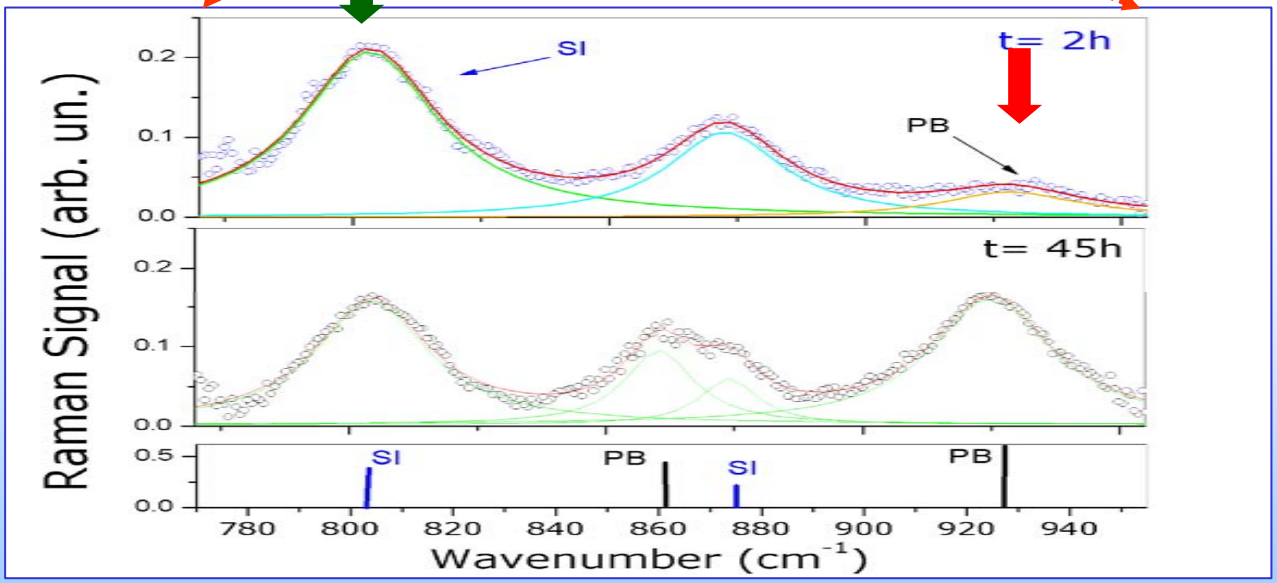


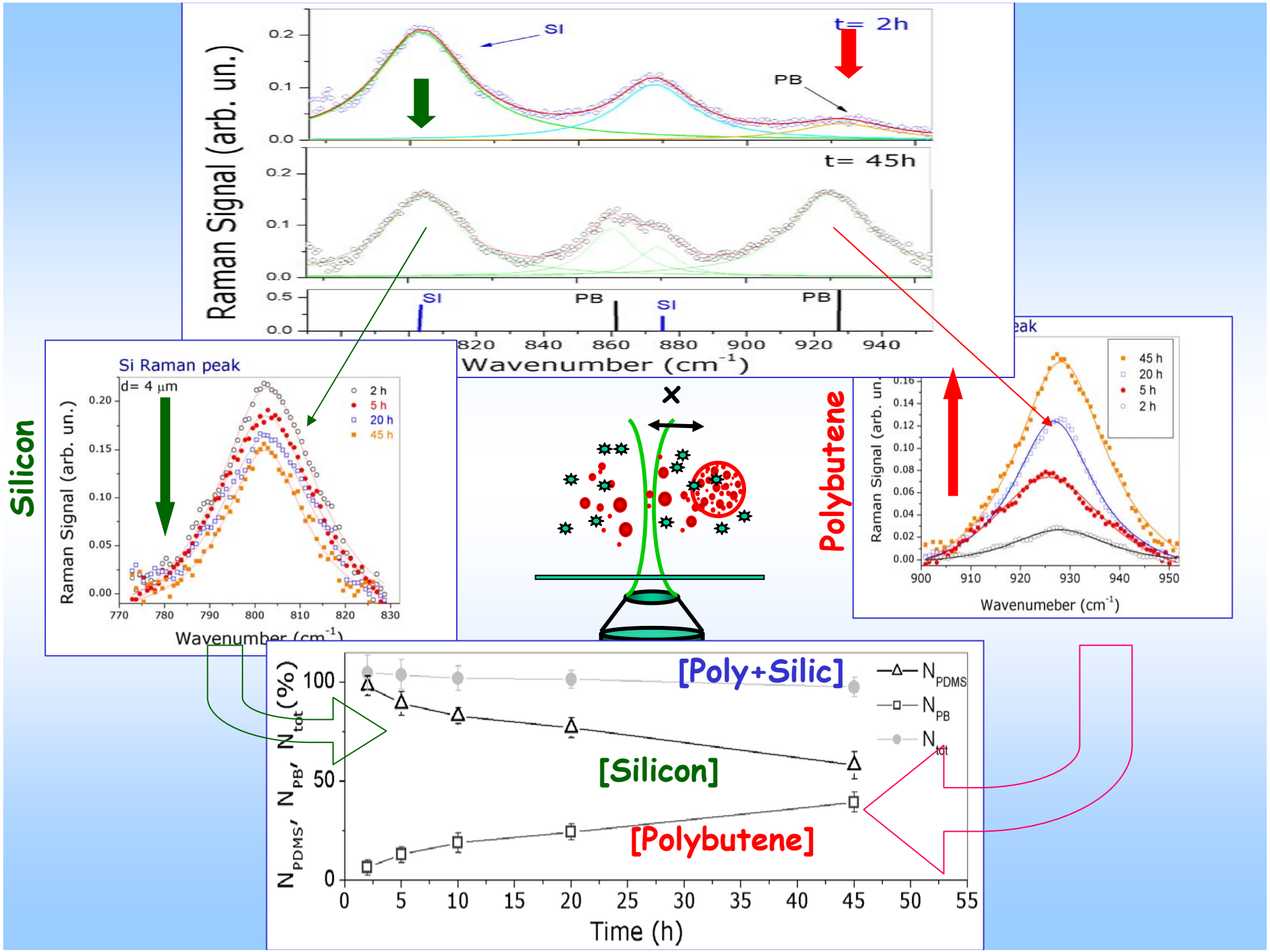
$$J = -D\nabla\Phi$$

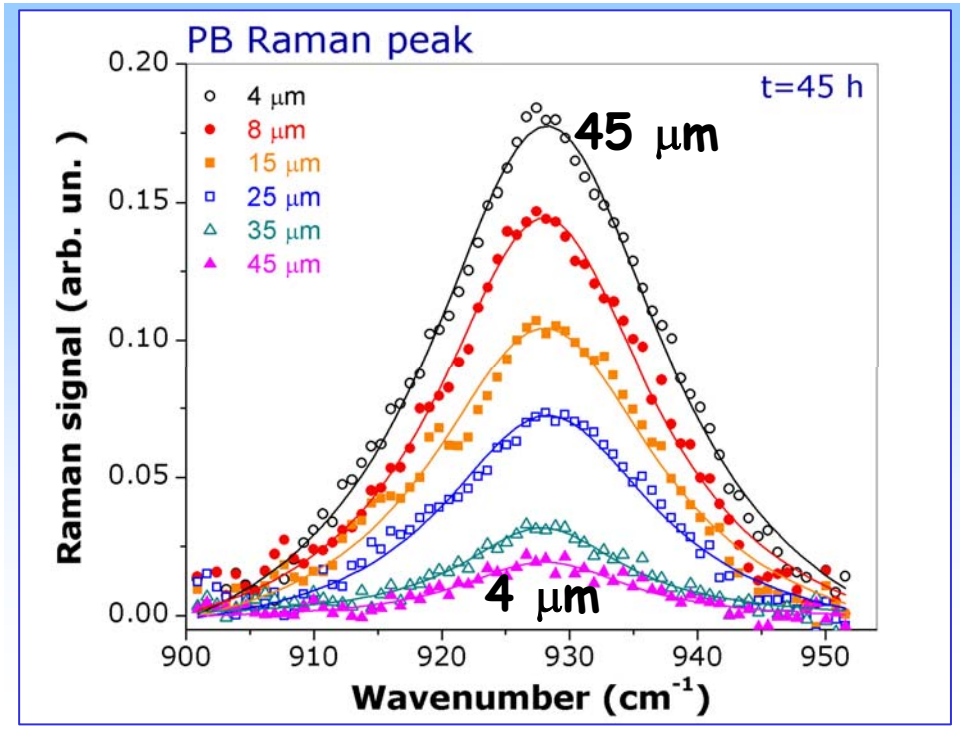
$$\frac{\partial\Phi}{\partial t} = D\nabla^2\Phi$$

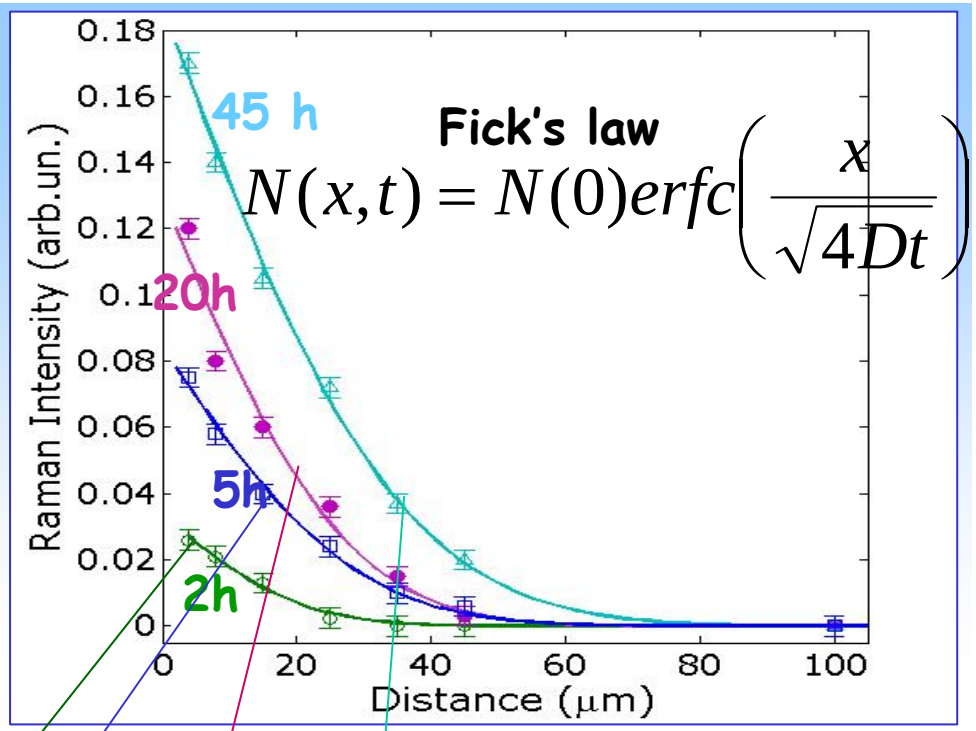


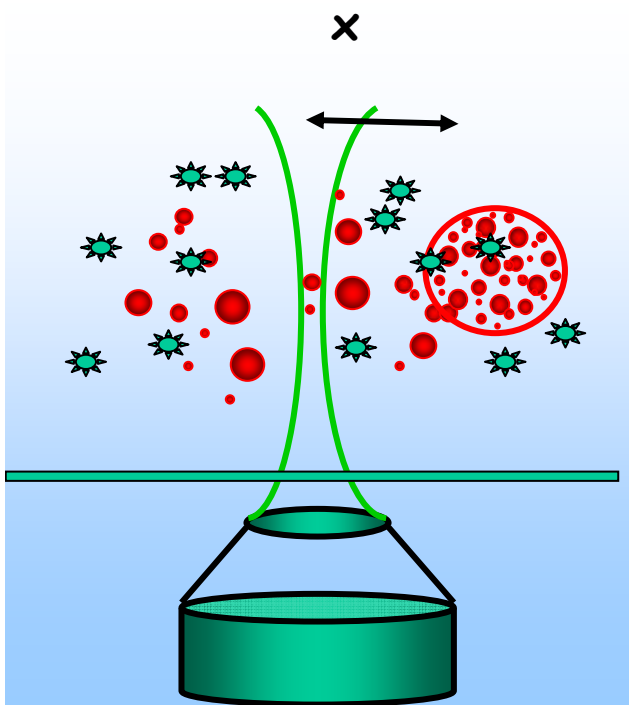

Polybutene
Silicon
Raman Signal (arb. un.)
Wavenumber (cm^{-1})

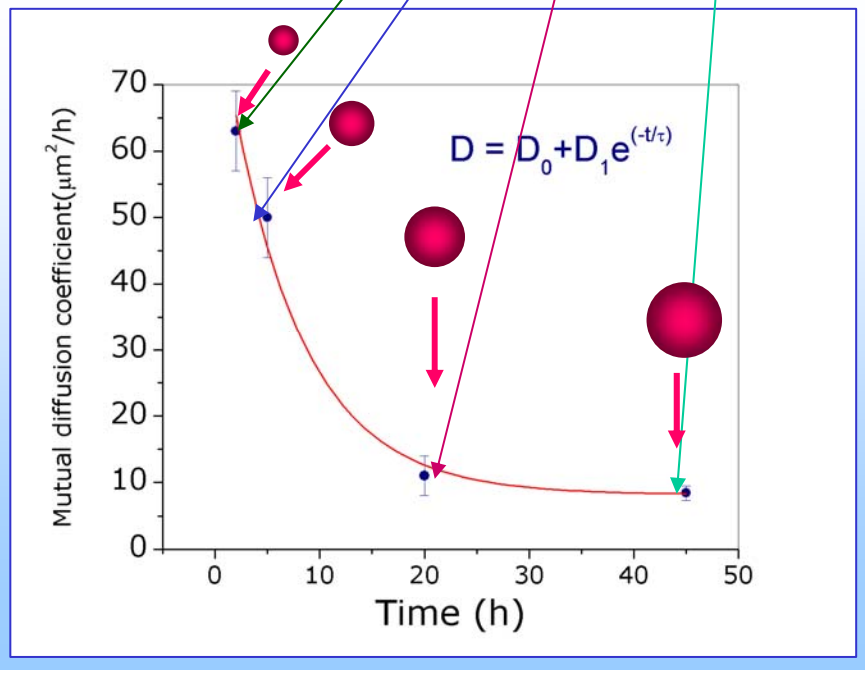

t= 2h
t= 45h
SI
PB
Raman Signal (arb. un.)
Wavenumber (cm^{-1})


Raman Signal (arb. un.)
t= 2h
t= 45h
SI
PB
Wavenumber (cm^{-1})
Silicon
Si Raman peak
d= 4 μm
2 h
5 h
20 h
45 h
Raman Signal (arb. un.)
Wavenumber (cm^{-1})
Polybutene
Raman Signal (arb. un.)
Wavenumeber (cm^{-1})
[Poly+Silic]
[Silicon]
[Polybutene]
N_{PDMS}
N_{PB}
N_{tot}
N_{PDMS}, N_{PB}, N_{tot} (%)
Time (h)

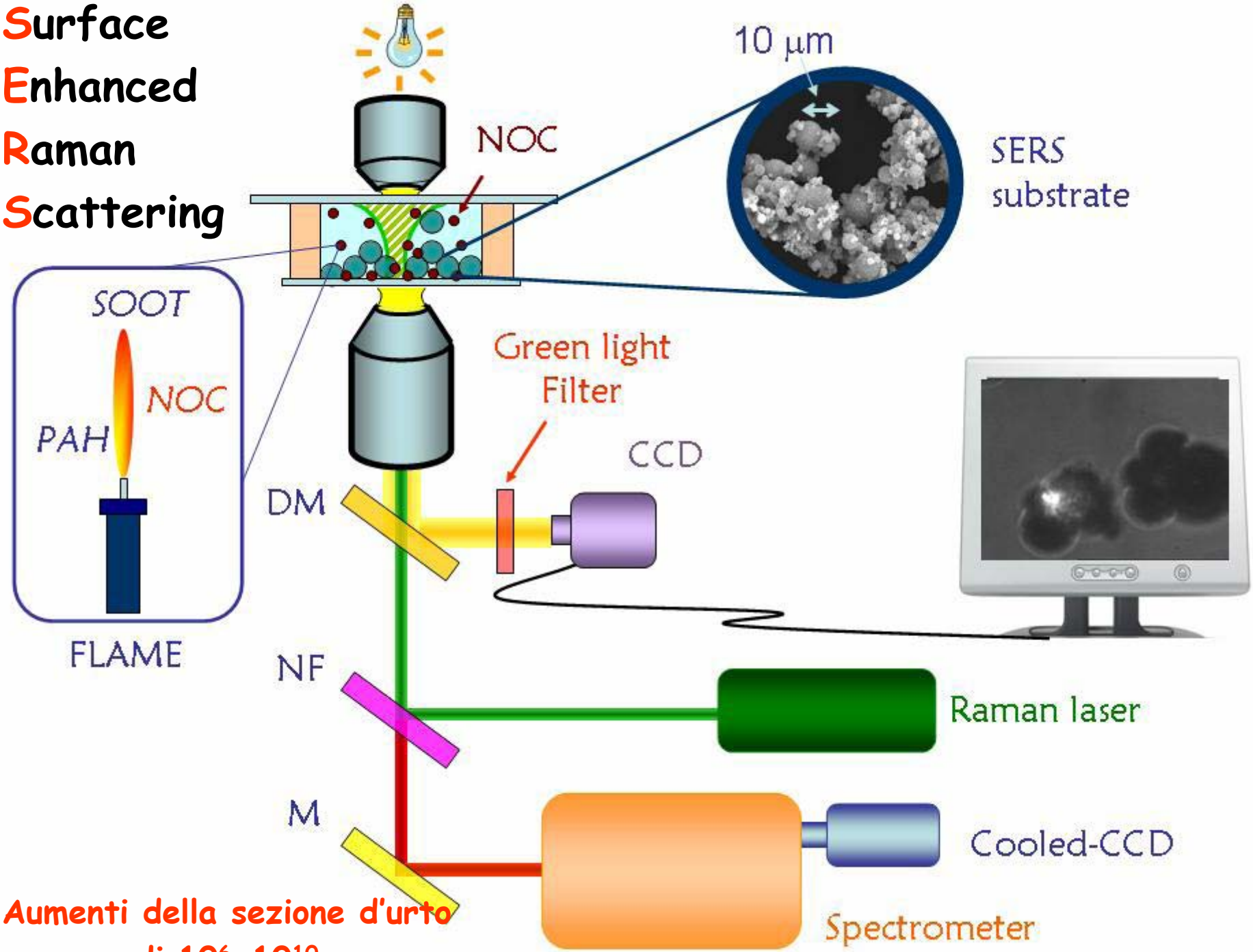

PB Raman peak
t=45 h
4 μm
8 μm
15 μm
25 μm
35 μm
45 μm
45 μm
4 μm
Raman signal (arb. un.)
Wavenumber (cm-1)
0.20
0.15
0.10
0.05
0.00
900
910
920
930
940
950


45 h
20h
5h
2h
Fick's law
$N(x,t) = N(0)erfc\left(\frac{x}{\sqrt{4Dt}}\right)$
Raman Intensity (arb.un.)
Distance (μm)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
20
40
60
80
100


x


$D = D_0 + D_1 e^{(-t/\tau)}$
Mutual diffusion coefficient(μm2/h)
Time (h)
70
60
50
40
30
20
10
0
0
10
20
30
40
50

Surface
Enhanced
Raman
Scattering

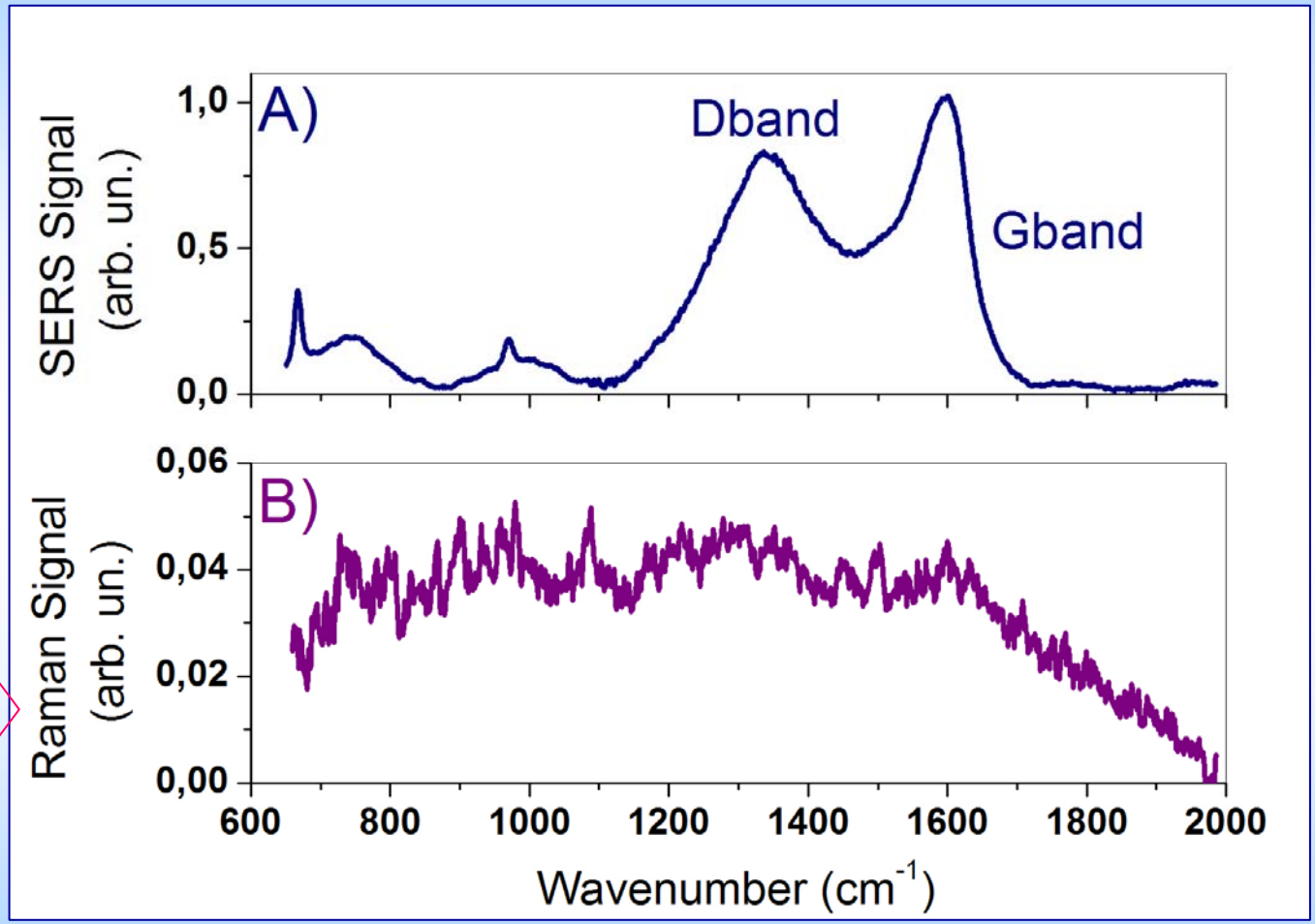


Aumenti della sezione d'urto di 10^6-10^{10}

SERS on carbonious nanoparticles produced in combustion processes

SERS

Normal Raman



G. Rusciano et al. *Carbon*, submitted

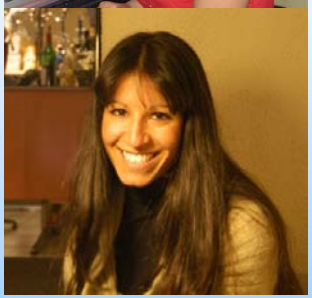
Aknowledgments:

- Giuseppe Pesce

- Giulia Rusciano

- A.C. De Luca (PhD)

- Lara Selvaggi (PhD)



- Antonio Caporali (dipl. Stud.)

cooperations:

- ✓Antonio D'Alessio (Dip. Ingegneria Chimica)
- ✓Stefano Guido (Dip. Ingegneria Chimica)
- ✓Paolo Netti (Dip. Ing.egneria Materiali.)
- ✓Luca Peliti (Dipartimento Scienze Fisiche)
- ✓Dmitri Petrov (ICFO, Barcellona)
- ✓Bruno Rotoli (Dip. Biochimica e Biotecnologie mediche)
- ✓Luigia Santella (Stazione Zoologica "A Dhorn", Napoli)