What happens when you pull on an axon ?

Chantal Tassius[1], Roberto Bernal[1,2] Pramod Pullarkat[3] & Francisco Melo[1]

[1] Laboratorio de Física No Lineal, Universidad de Santiago, Chile

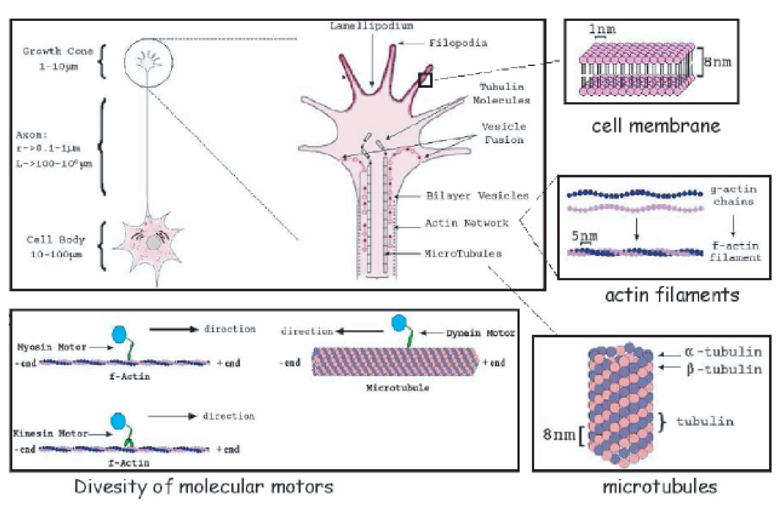
[2] Department of Organismic and Evolutionary Biology, Harvard University, Boston, USA

[3] University of Bayreuth, Germany

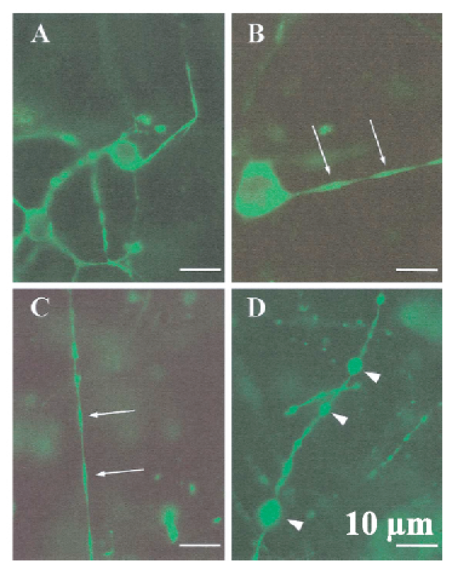
contact: ctassius@fisica.usach.cl

1. Biological system

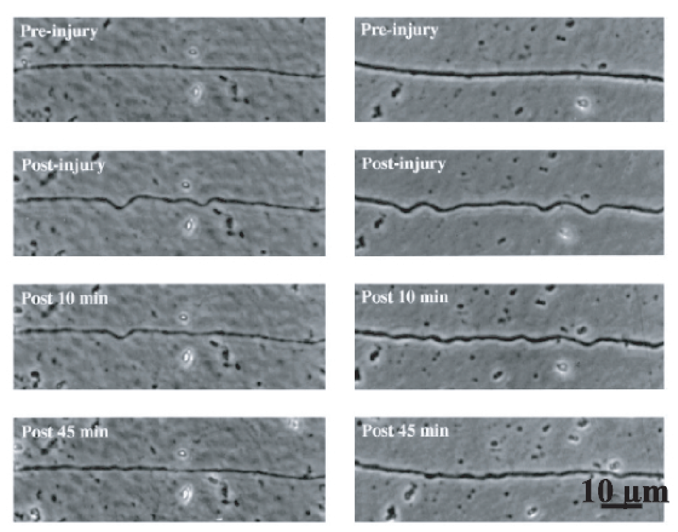
Neurons and axons basic components:



Morphological anomalies observed under stress:



Oxidative stress induces axonal beading in cultured human brain tissue [Roediger & Armati, 2003]

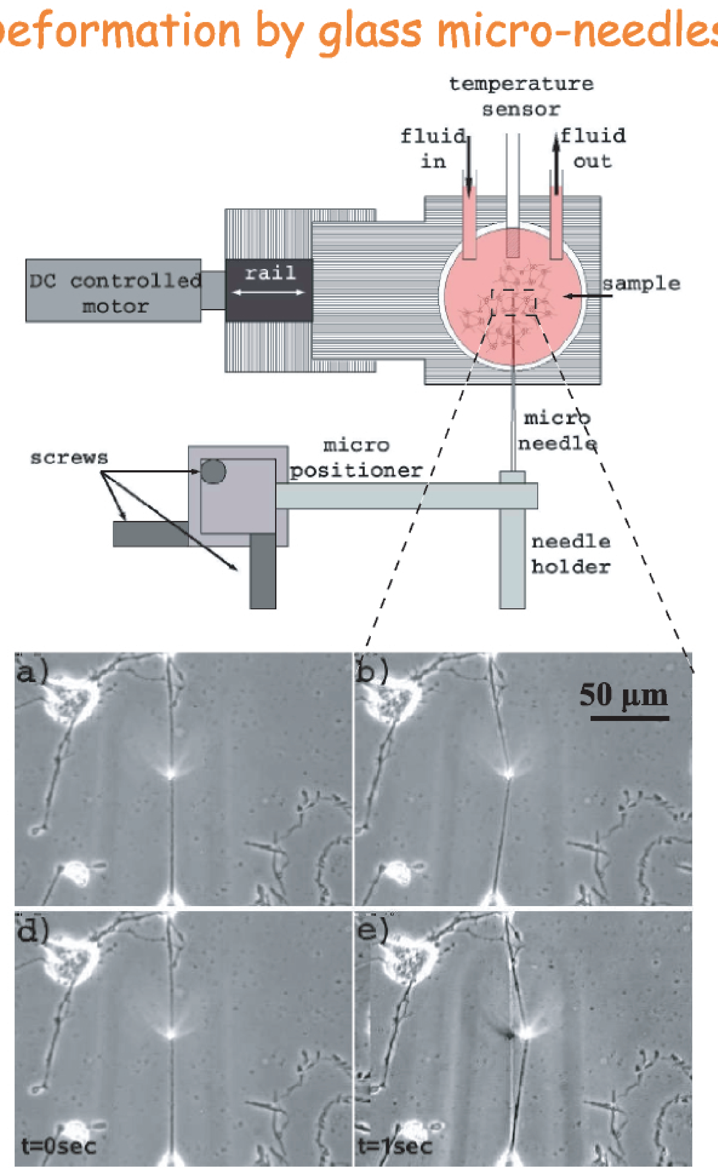


High Tolerance and Delayed Elastic Response of Cultured Axons to Dynamic Stretch Injury [Smith & *al.*, 1999]

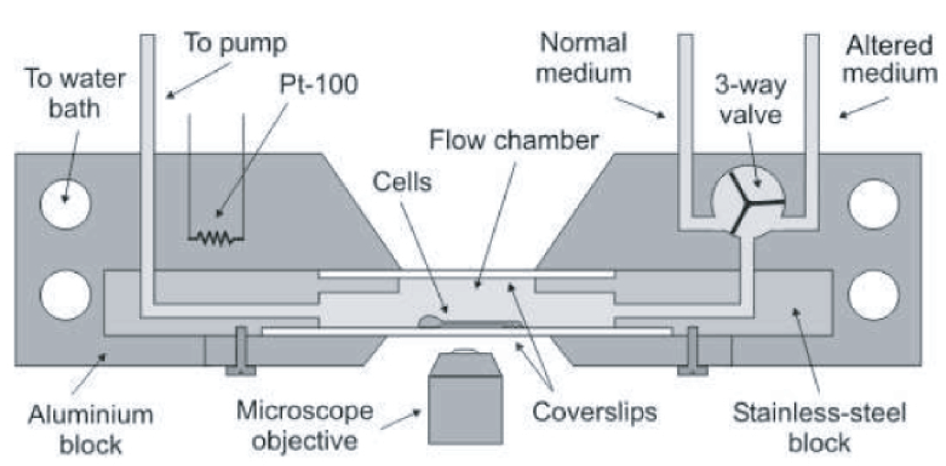
Are we able to probe the mechanical characteristics of axons ?

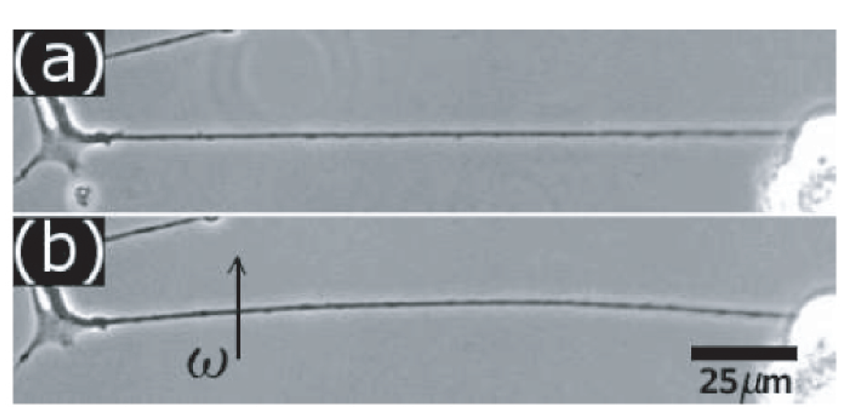
2. Experimental set-ups

Deformation by glass micro-needles:



Deformation by a hydrodynamic flow:





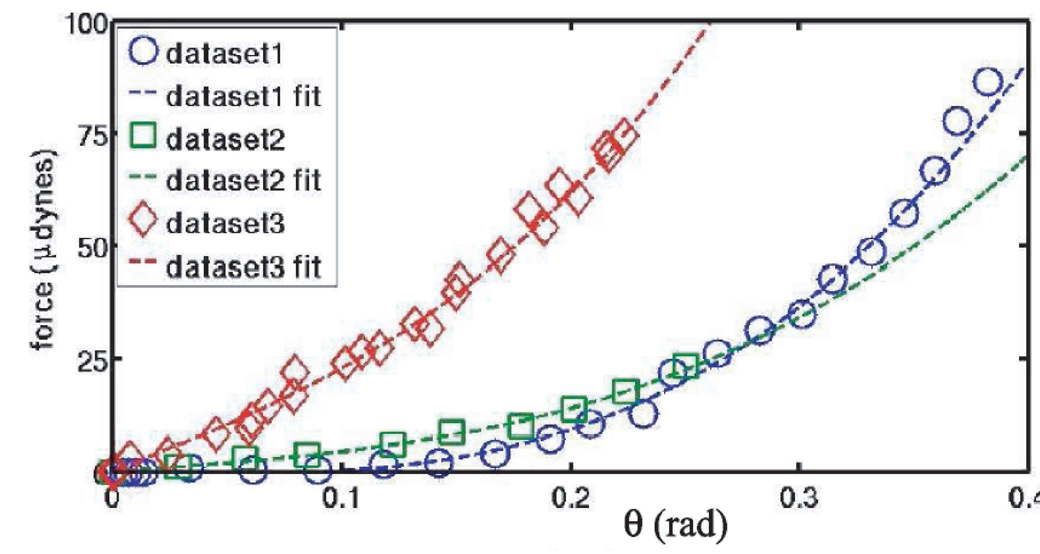
ω: viscous drag

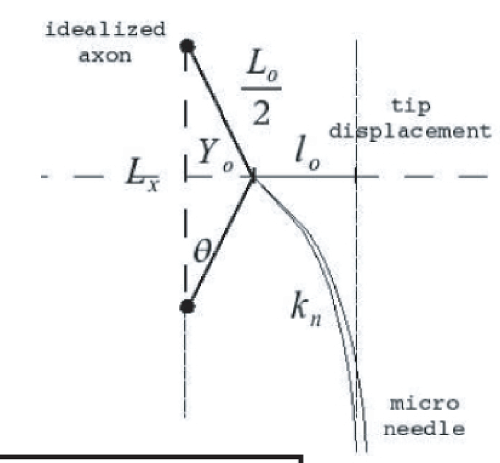
P. Pullarkat
Bayreuth, Germany

3. Results

From micro-needle experiments:

• Elastic behavior: $\tau \sim 1s$

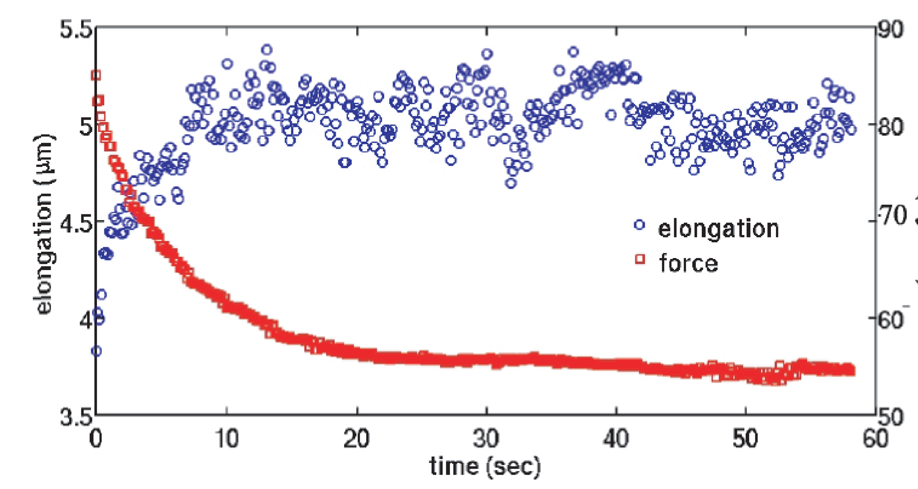




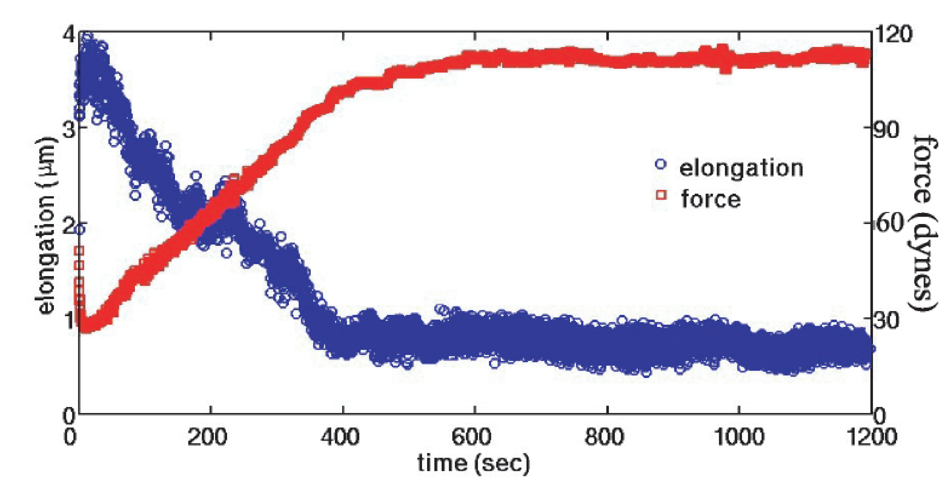
$$F_{needle} = \kappa \frac{L_x}{2}\theta^3 + 2T_o\theta$$

Excellent fit of experimental data by a relation derivated from a Hooke's law hypothesis → T_0, κ

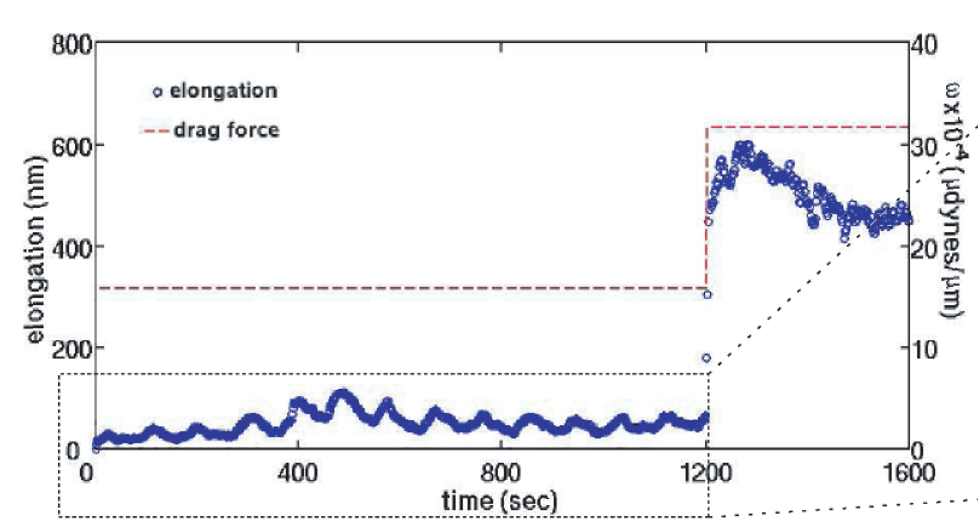
• Viscoelastic behavior: $\tau \sim 10s$

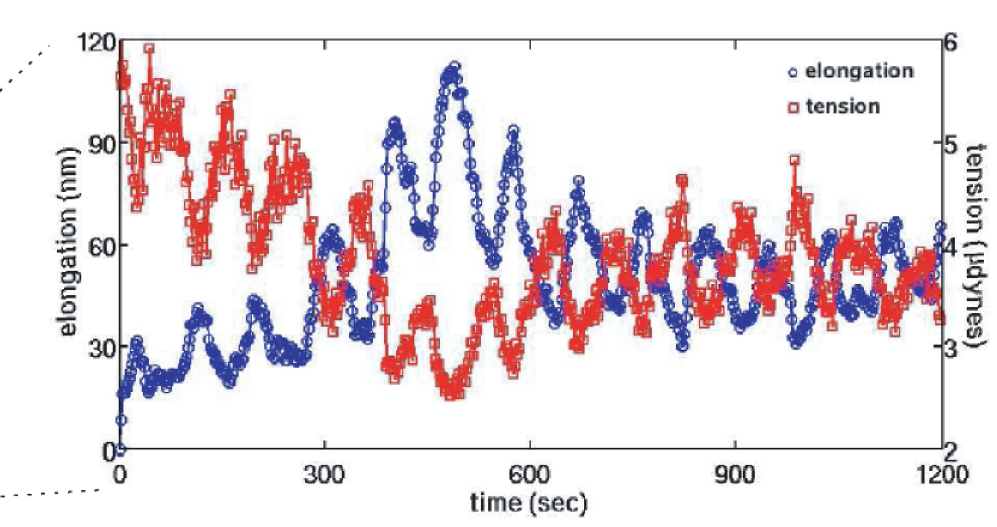


• "Active" behavior: $\tau \sim 100s$



From hydrodynamic flow experiments:

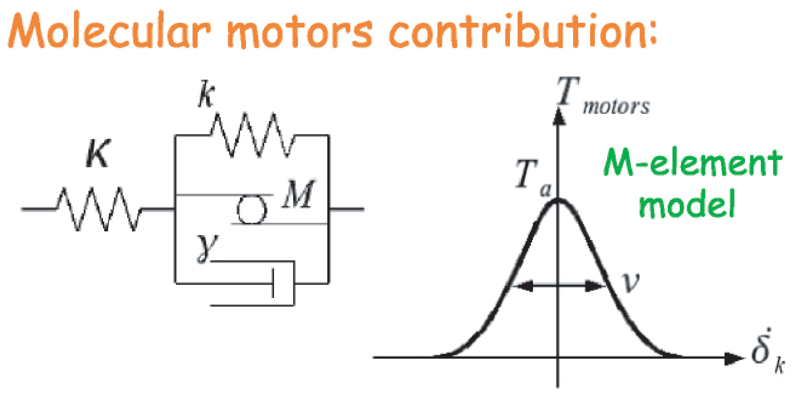




Axon elongation oscillations tuned by intensity of the drag flow

4. Model proposed *

Molecular motors contribution:



Equilibrium equation:

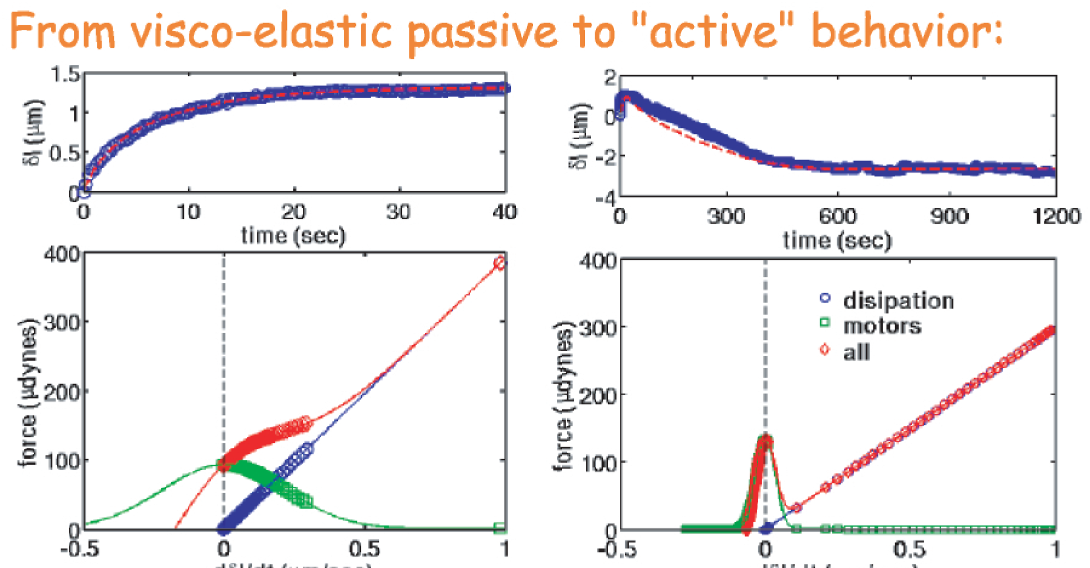
$$\beta\gamma\dot{\delta l} + T_a e^{-\beta^2\dot{\delta l}^2/v^2} + k\left(\beta + \frac{k_n}{2\alpha k}\right)\delta l = \frac{k_n}{2\alpha} l_o$$

dissipation; motors contribution; elastic elongation; external load

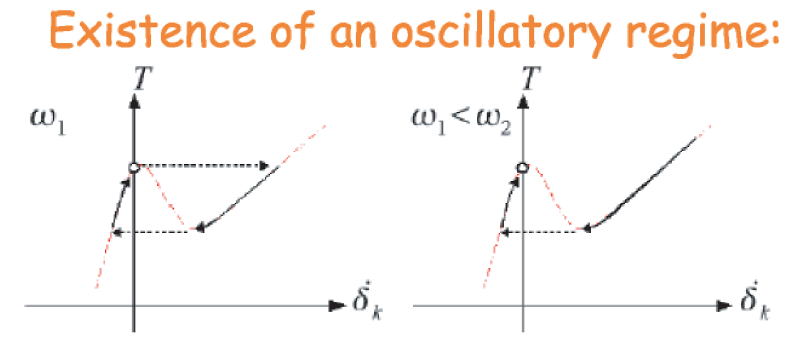
$$\alpha = \sin\theta_o$$

$$\beta = (\alpha + k_n/2\alpha\kappa)$$

From visco-elastic passive to "active" behavior:



Existence of an oscillatory regime:



*R. Bernal & F. Melo

5. Perspectives

Can the mechanics of axons be described by a two-state model ?

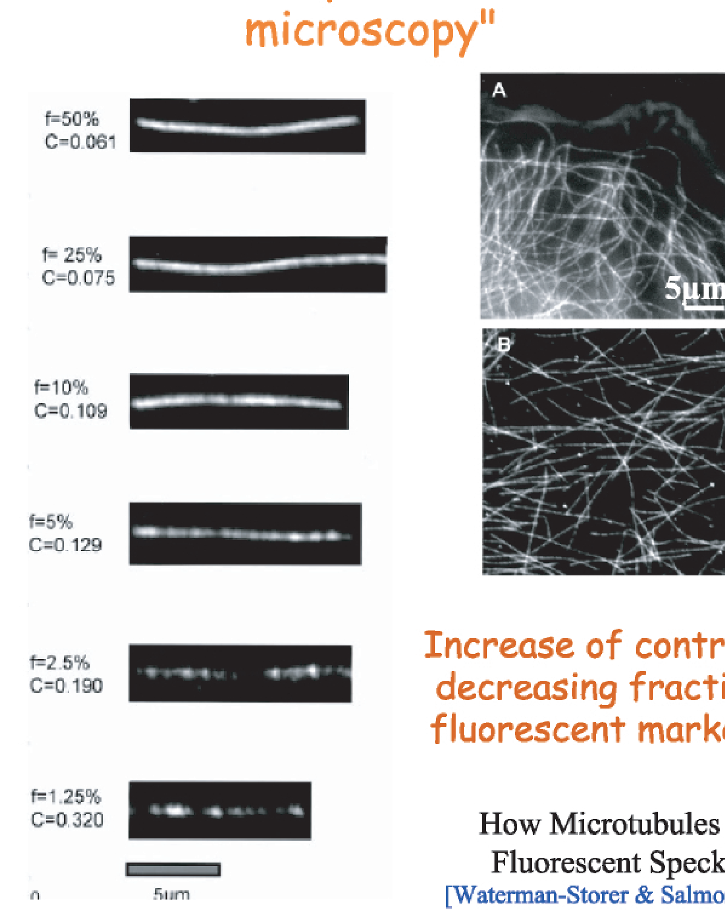
↓

Do we have alternance of contracted and elongated segments along the axon under this type of applied stess ?

↓

Are we able to measure local deformation along the axon ?

Idea: use of "speckle fluorescence microscopy"



Increase of contrast (C) decreasing fraction of fluorescent markers (f)

How Microtubules Get Fluorescent Speckles [Waterman-Storer & Salmon, 1998]

IV Jornada CIMAT, Reñaca, Chile (2006)