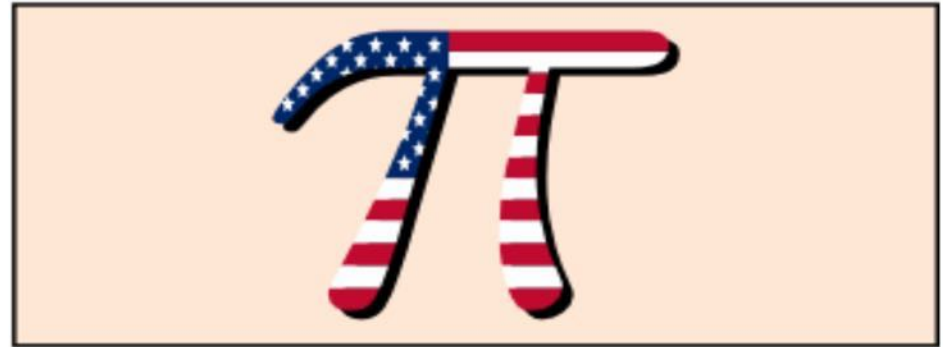


Movie title 1

$$9.80665 \text{ m/s}^2$$

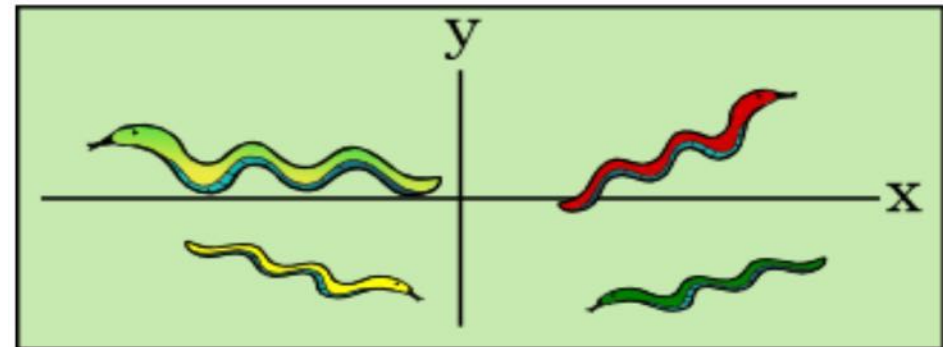
Movie title 2



Movie title 3

$$\left| \frac{ds}{dt} \right|$$


Movie title 4



Movie title 5

1609.344 METRES

Movie title 6

$$\frac{1}{n} \sum_{i=1}^n$$


i

Torsion and the brain

Michel DESTRADE

Chair of Applied Mathematics,

NUI Galway

Adjunct Professor,
University College Dublin,
Zhejiang University.



NUI Galway
OÉ Gaillimh

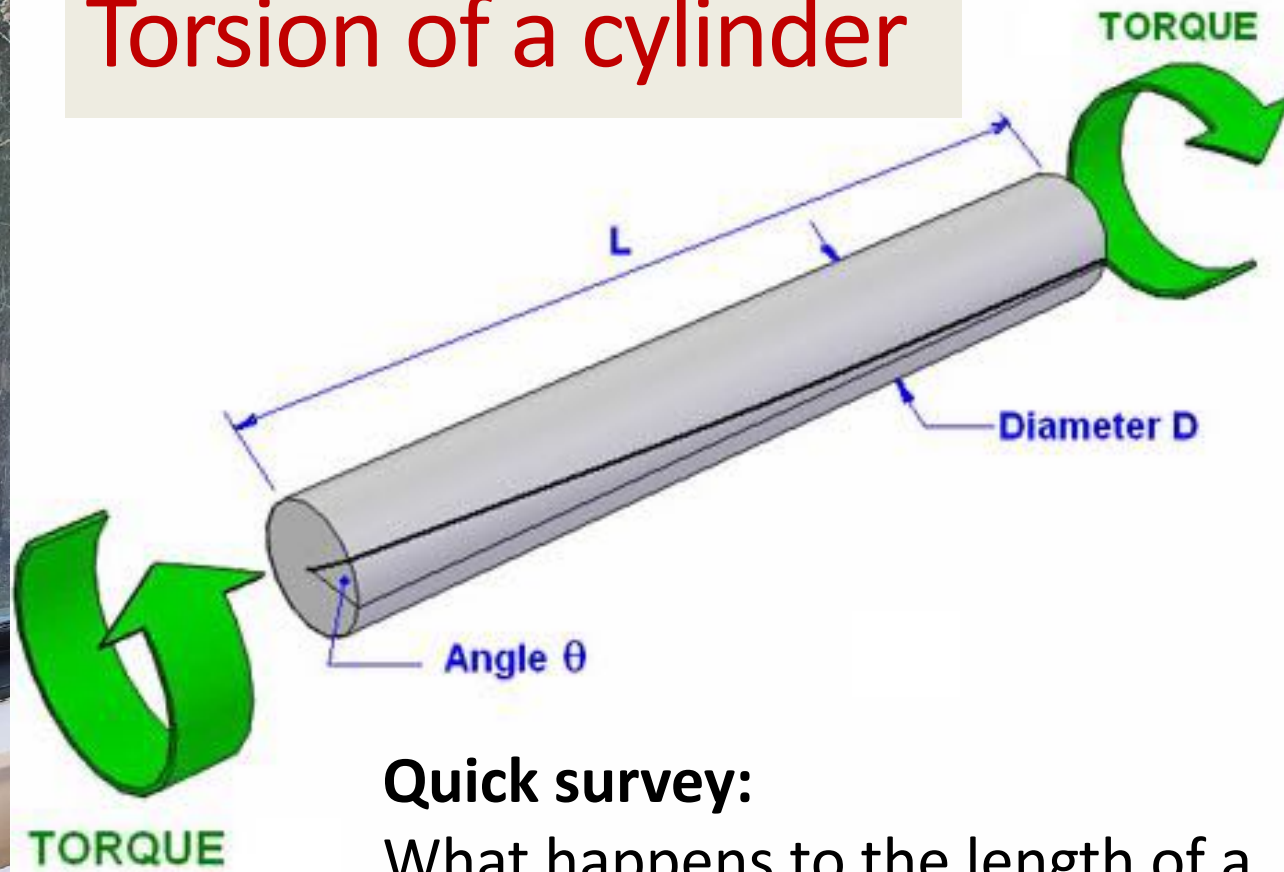


HV 10.0 kV mag 3,500 x HFW 42.6 μ m VWD 6.2 mm curr 82.9 nA tilt -0.0° det ---

10 μ m



Torsion of a cylinder



Quick survey:

What happens to the length of a cylinder when you twist it?

1. Increases (cylinder lengthens);
2. Decreases (cylinder shortens);
3. Stays the same;
4. I don't know.

Torsion of a cylinder: The POYNTING effect

Watch the YOUTUBE video at

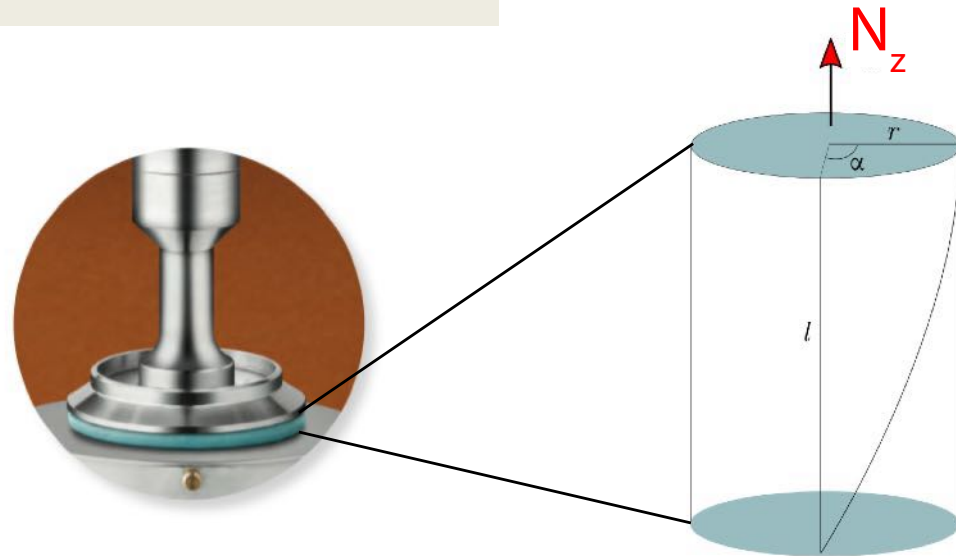
<https://www.youtube.com/watch?v=ugD6PsDaLu4>

Zurlo et al. 'The Poynting effect'. *American Journal of Physics* (to appear)

Torsion testing of brain matter

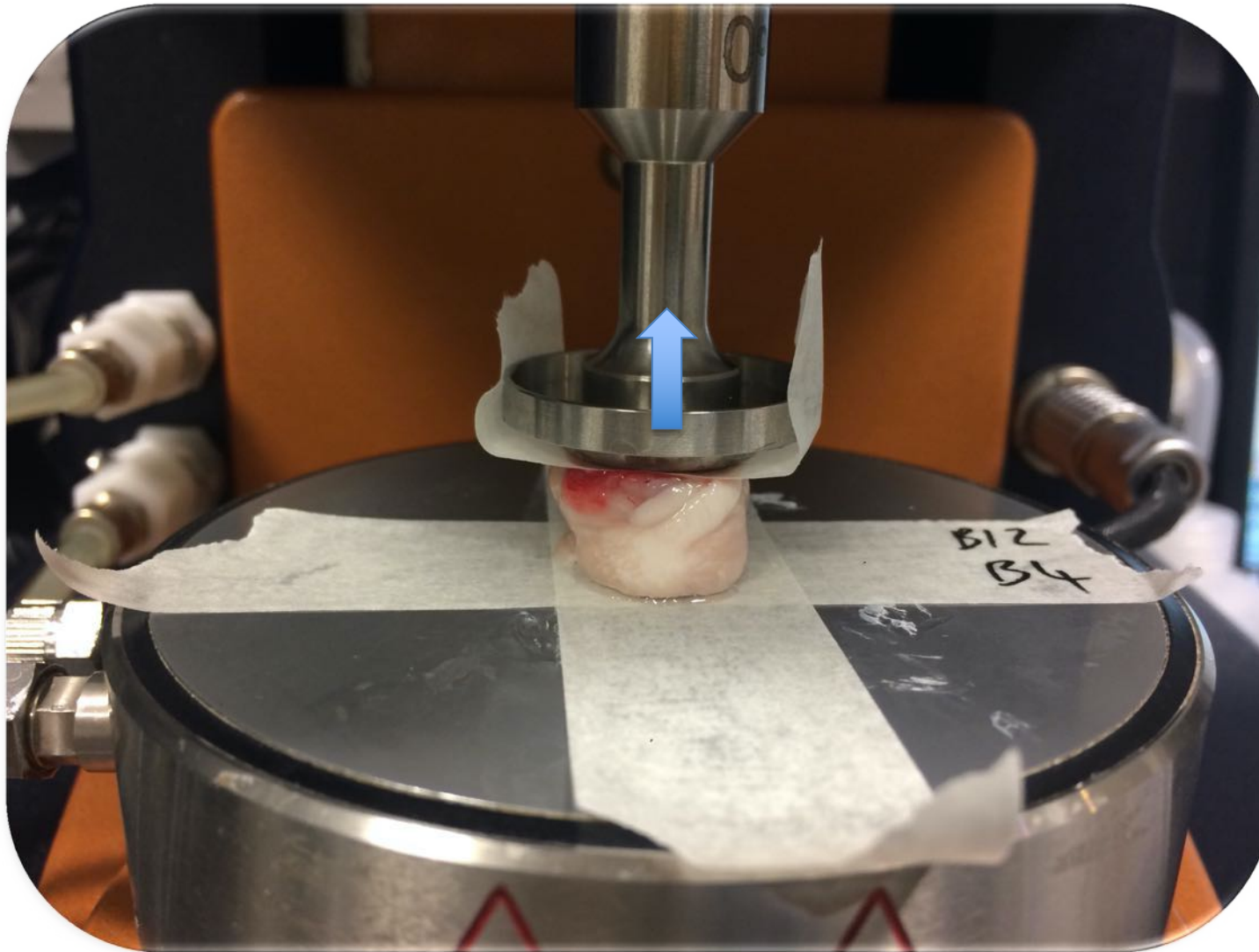


Discovery Hybrid 2 rheometer



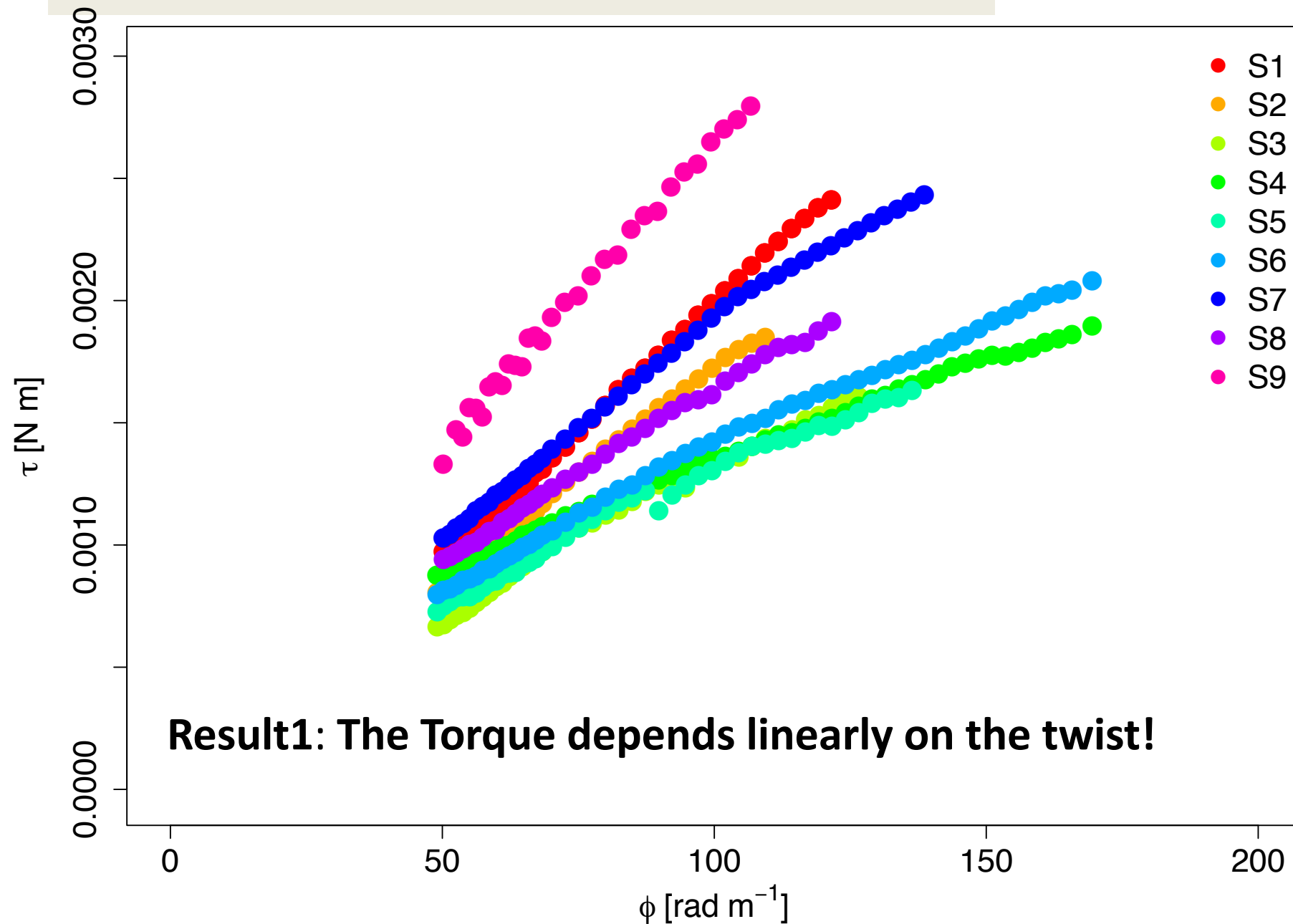
The rheometer measures the torque τ and normal force N_z required to twist a cylindrical sample by an angle α .

Poynting effect in torsion

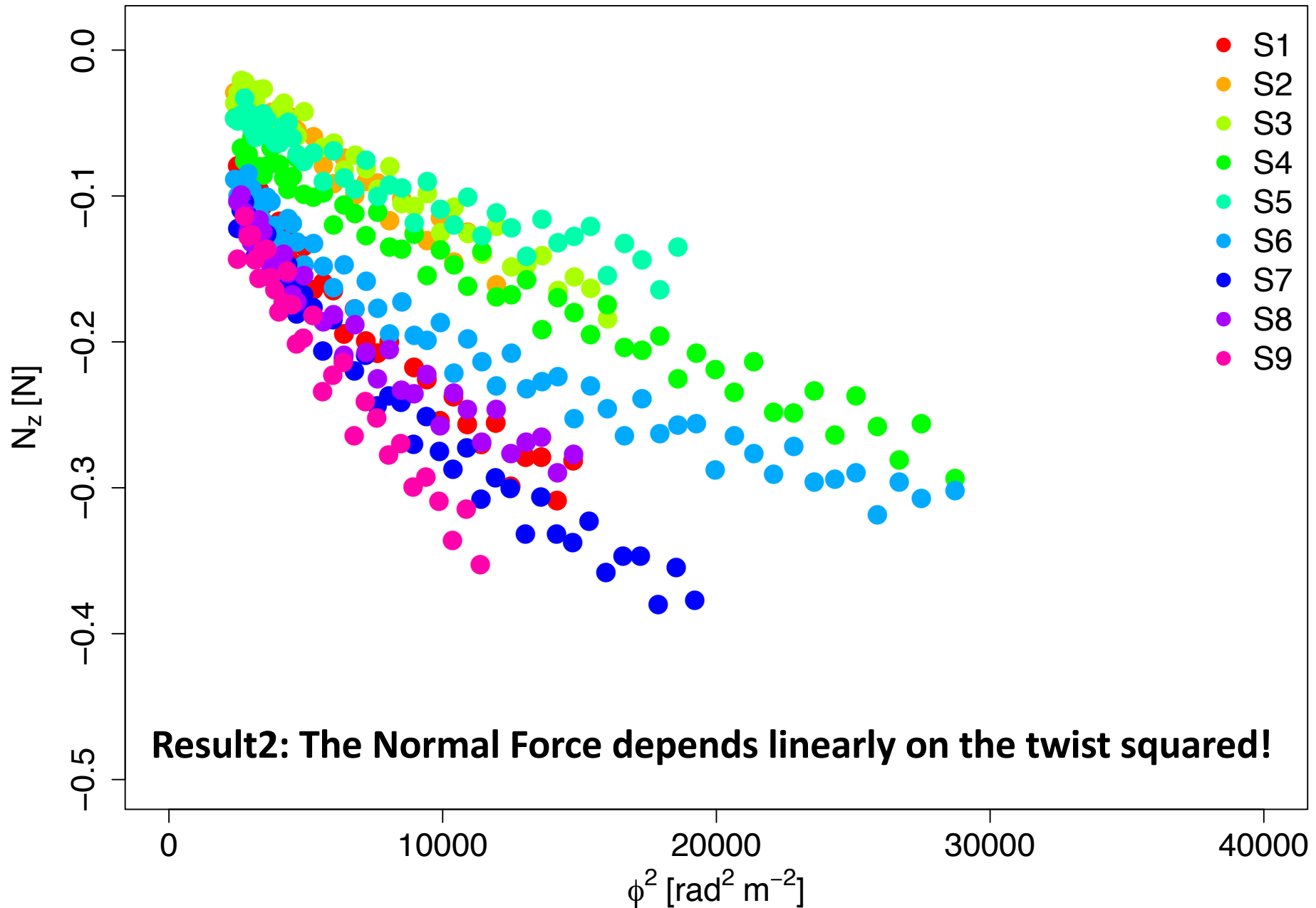


The sample is pushing up against the top plate

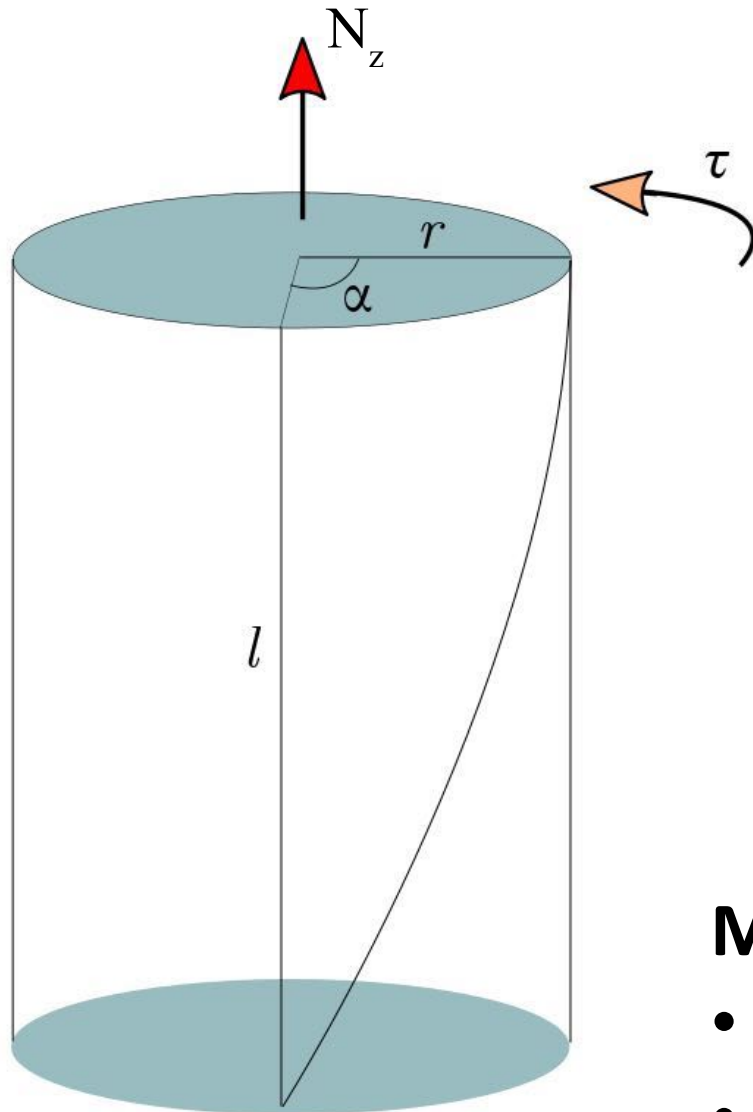
Experimental data: Torque



Experimental data: Normal force



Modelling the torsion



Deformation:

$$\begin{cases} r &= \frac{1}{\sqrt{\lambda}} R \\ \theta &= \Theta + \phi \lambda Z \\ z &= \lambda Z \end{cases}$$

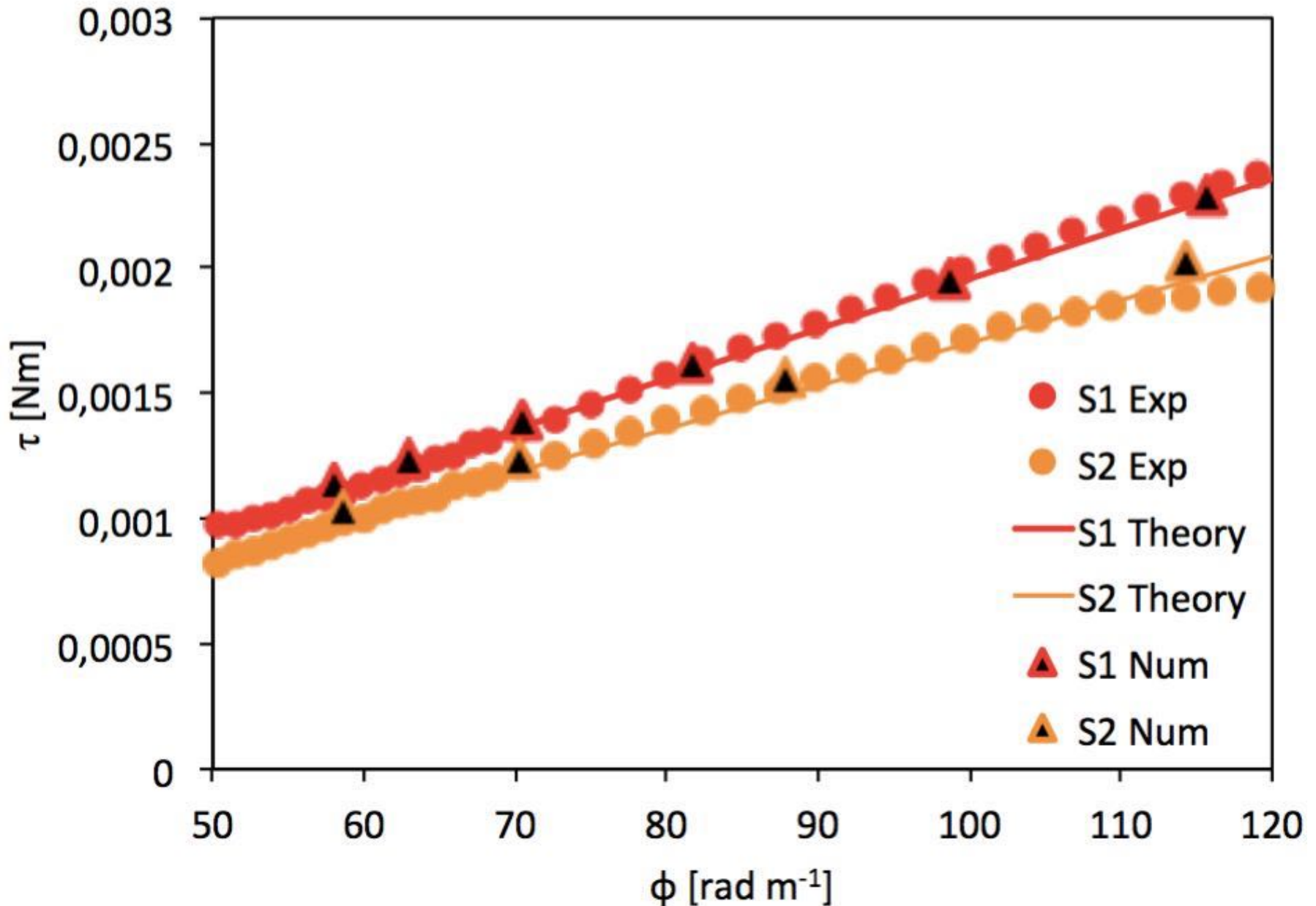
Twist: $\phi = \alpha/l$

Longitudinal stretch: λ

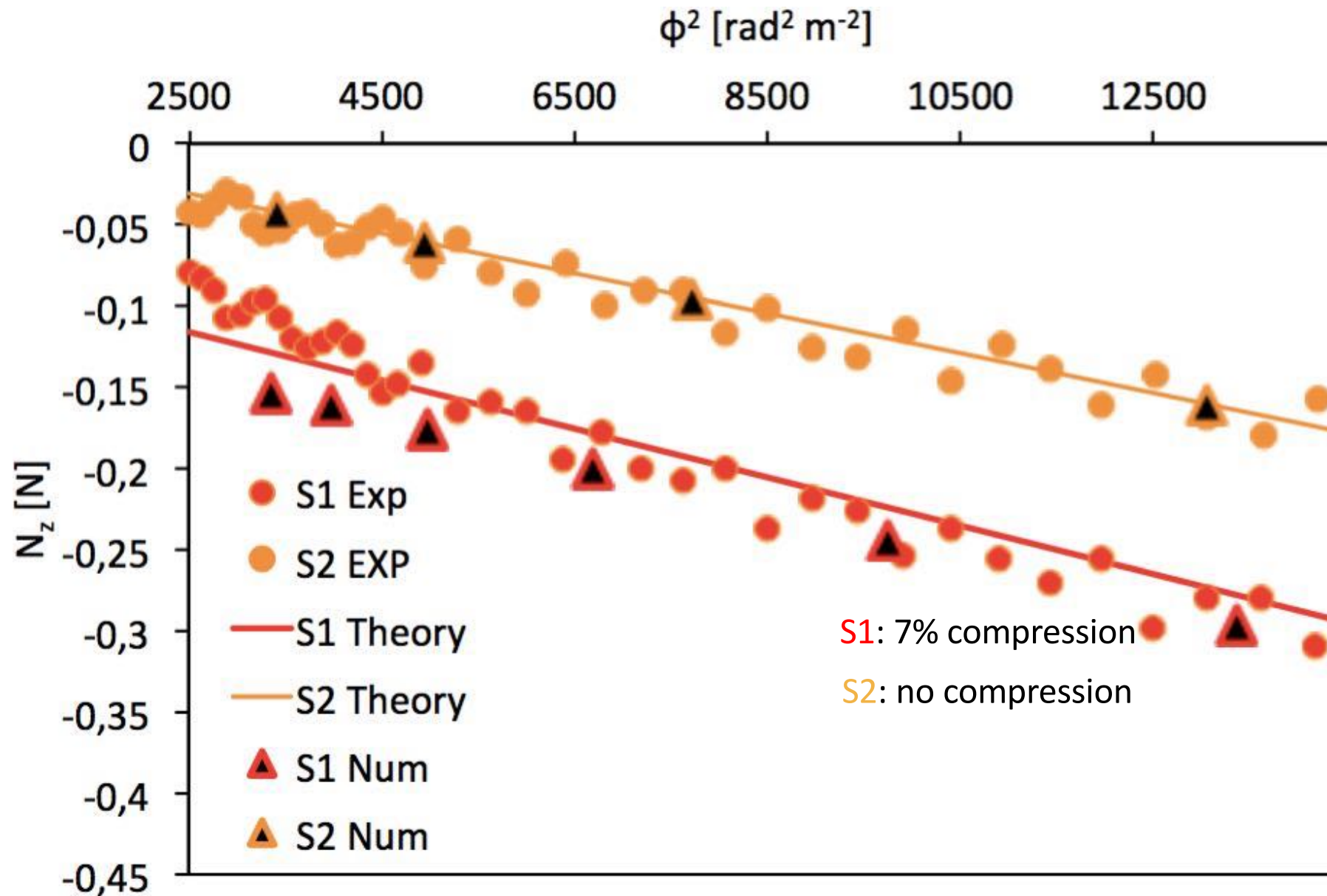
Mooney-Rivlin model predicts

- Torque $\propto \phi$
- Normal force $\propto \phi^2$

Torsion in Abaqus: Torque



Torsion in Abaqus: Normal force



Conclusions

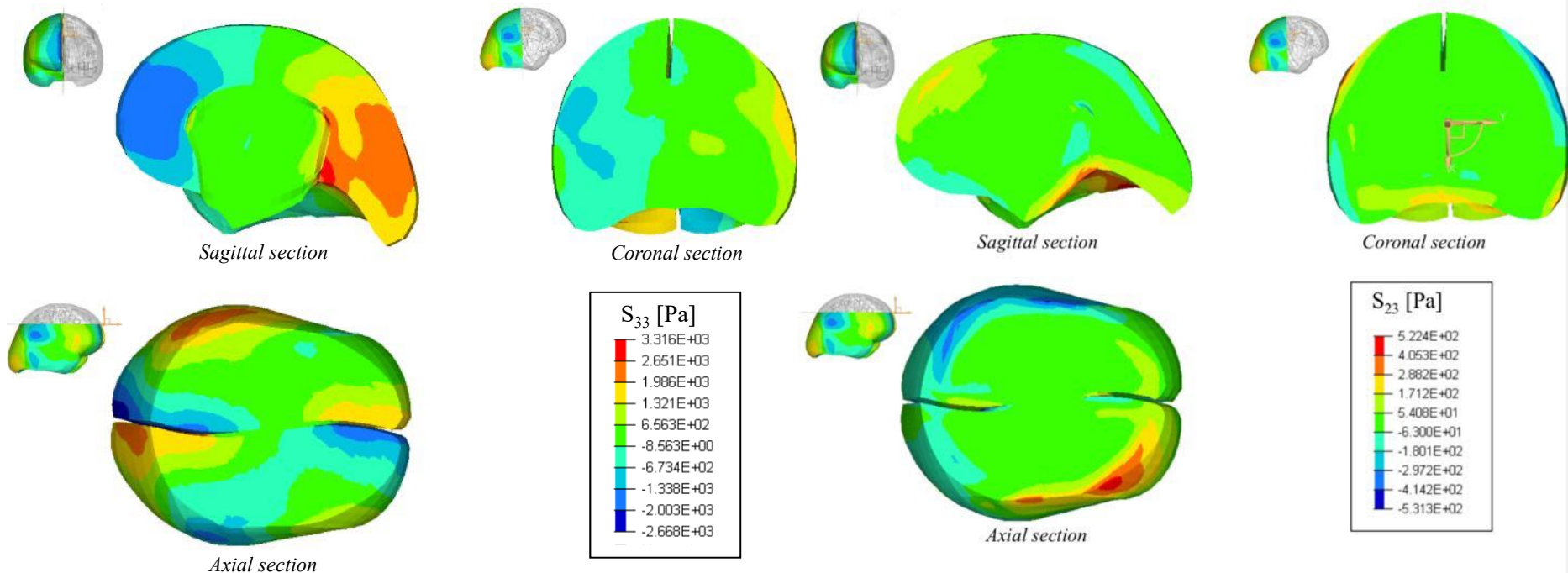
sample	μ [Pa]	c_2 [Pa]	R_τ^2	$R_{N_z}^2$
S_1	1232.50	294.45	0.999	0.946
S_2	1092.31	235.84	0.998	0.939
S_3	766.95	310.60	0.988	0.966
S_4	491.14	201.22	0.996	0.958
S_5	656.96	59.68	0.988	0.87
S_6	644.59	113.75	0.994	0.92
S_7	952.36	347.26	0.993	0.947
S_8	803.12	401.41	0.997	0.925
S_9	1460.17	710.29	0.995	0.962
mean \pm SD	900 \pm 312	297 \pm 189		

Estimated elastic parameters:

shear modulus $\mu=2(c_1+c_2)$,
Mooney-Rivlin parameter c_2 and
the two coefficients of determination
for the torque (R_τ^2) and the normal
force ($R_{N_z}^2$) data fits.

1. Brain displays the classical **Positive Poynting Effect** in torsion
2. Brain **behaves as a Mooney-Rivlin material** in torsion

Simulation: Rotational head impact



Normal component

Shear component

Peak acceleration: $2,170 \text{ rad s}^{-2}$ (thresholds for mild DAI are $>5,000 \text{ rad s}^{-2}$)

Normal and shear stress are of the same order of magnitude (kPa) as thresholds for DAI (Deck & Willinger, 2008)

[Soft Matter, 2019]

The destructive brain team



V. Balbi (UL)



A. Ní Annaidh and A. Trotta (UCD)



Conclusion

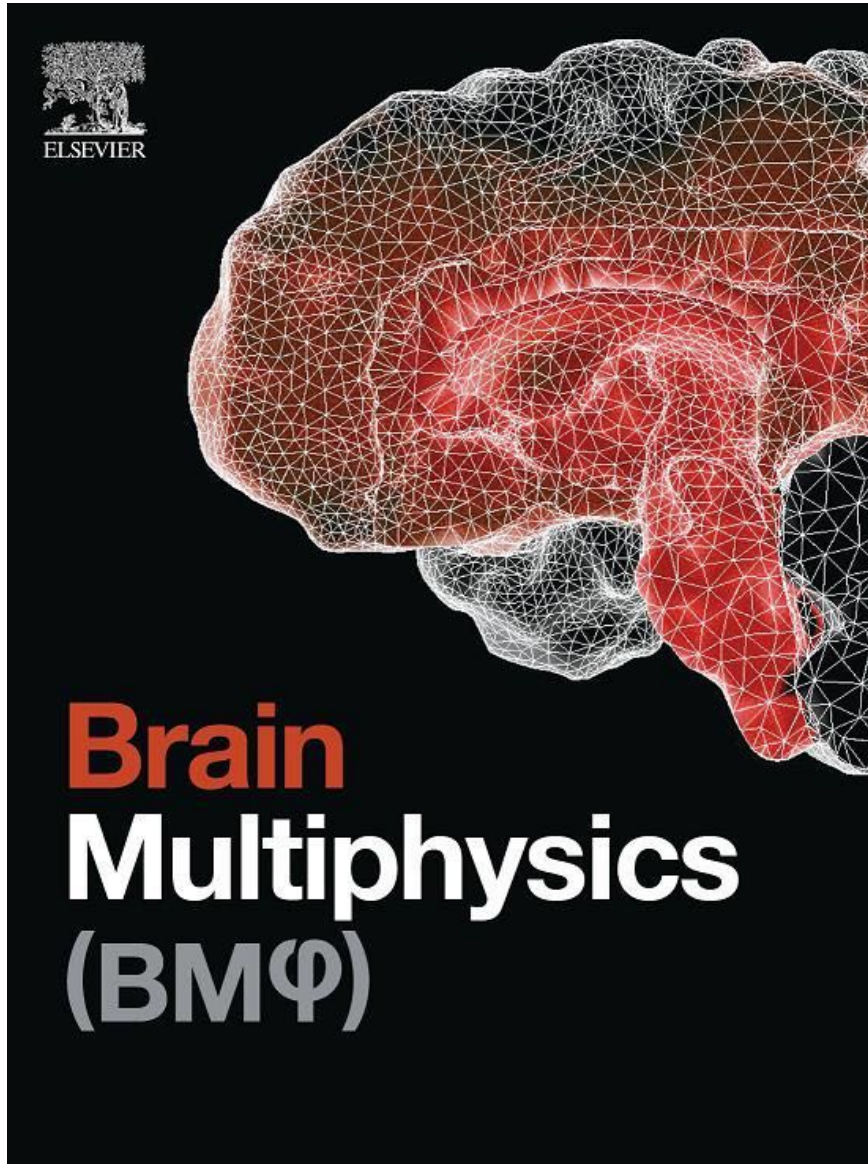


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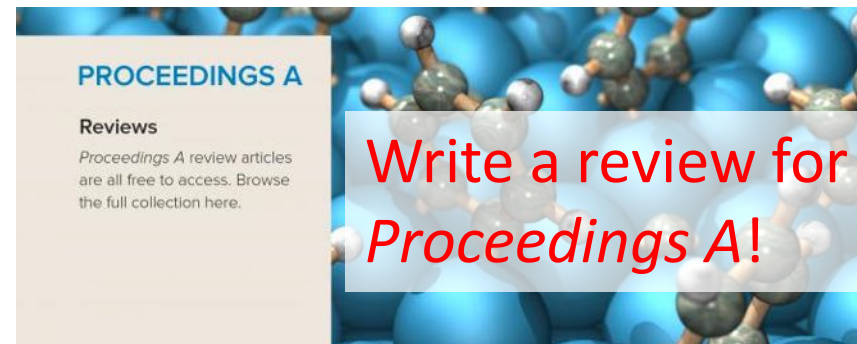
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