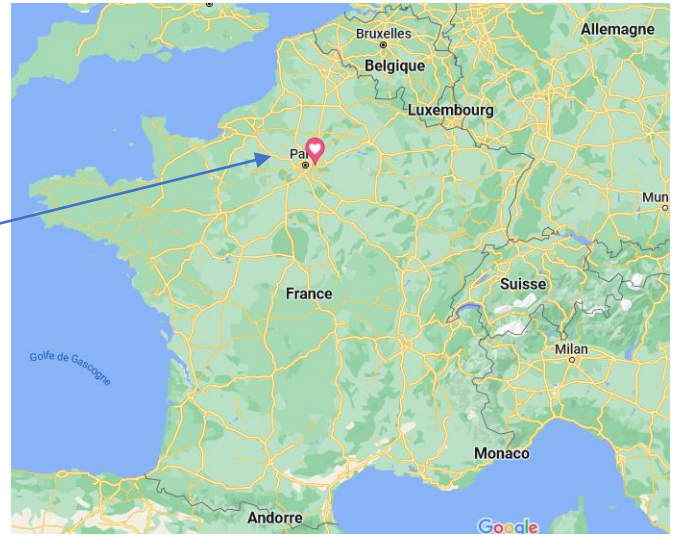
Minisymposium MS10
31 may 2022

Imaging fluid transfers in pores and pore changes through *dynamic* NMR relaxometry

Benjamin Maillet *(oral presenter), Philippe Coussot, Rahima Sidi-Boulenouar, Jérôme Suard, Thibault Lerouge (Navier laboratory)*



Bienvenue building, Champs-sur-Marne France

Ecole des ponts et chaussées, Champs-sur-Marne France

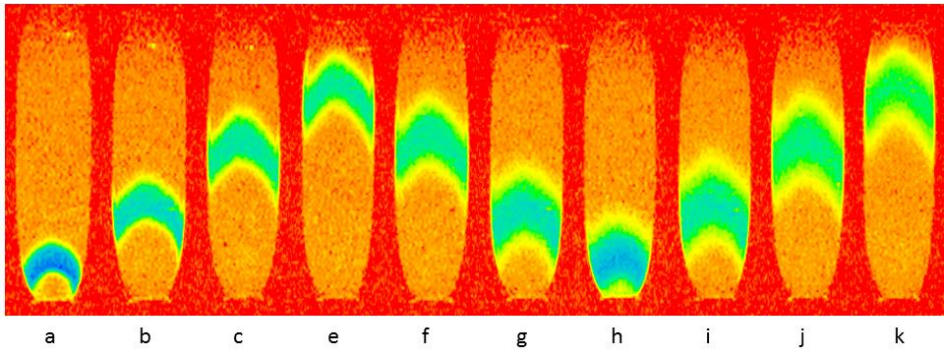
Introduction.

Interaction **liquid water porous media**
→ Key concept **for building materials**

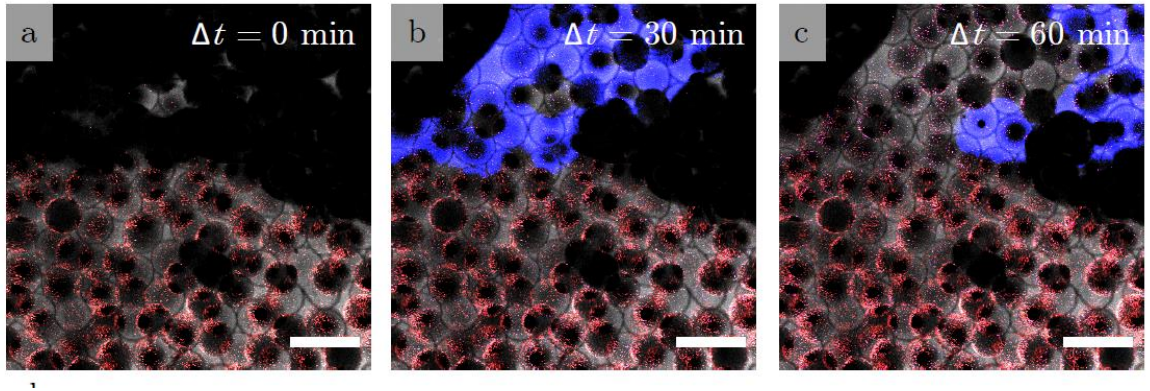
Wood imbibition

Wood storage

IRM and other imagery techniques
→ **Qualitative local information**



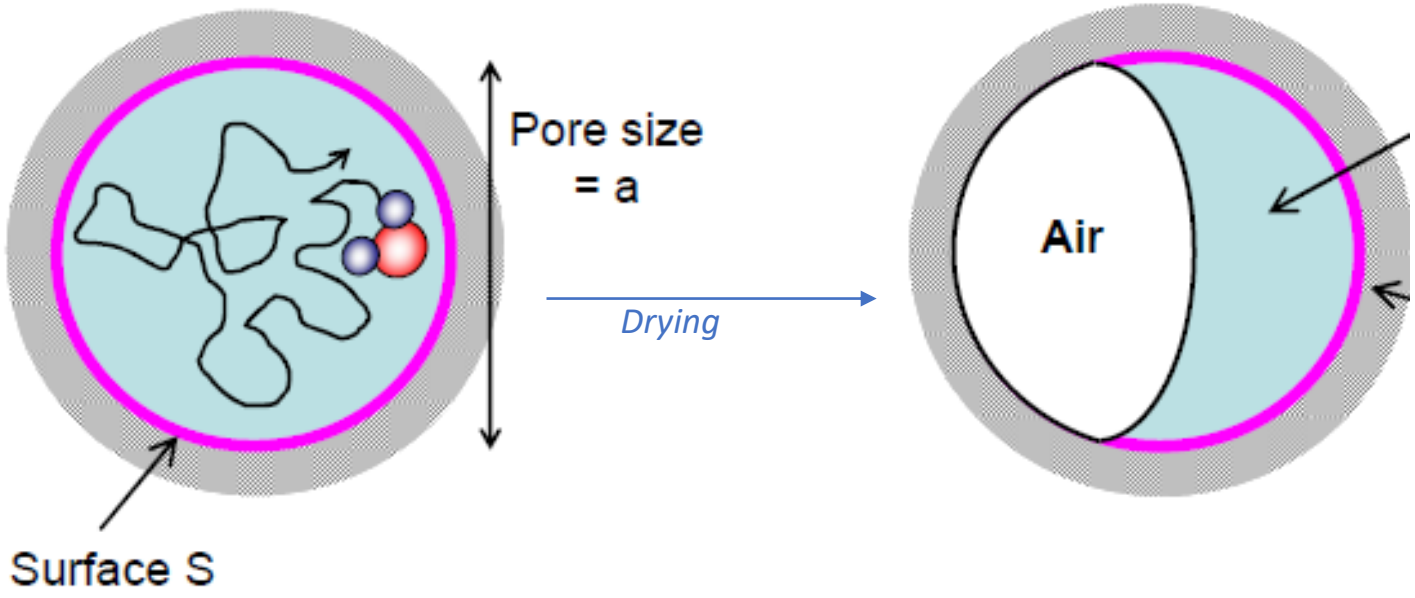
Lehoux et al, Physical Review E, 2016



Using colloidal deposition to mobilize immiscible fluids from porous media
Joanna Schneider, Rodney D. Priestley, and Sujit S. Datta
Phys. Rev. Fluids, 2021

« Dynamic » NMR
→ **No invasive multiscale quantitative full description of water transfer over time**

The relaxation time in porous media



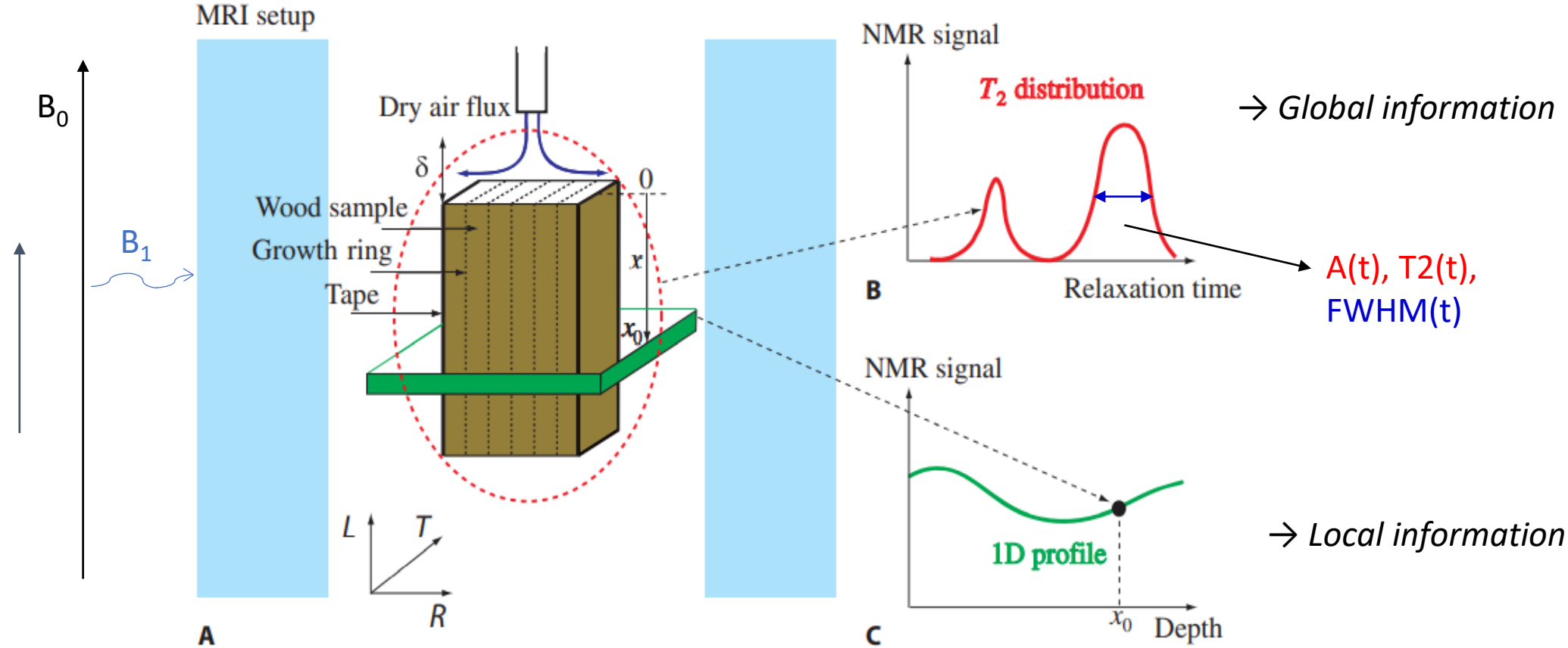
Tarr and Brownstein theory (1978): $\frac{1}{T_{2,\,pore}} - \frac{1}{T_{2,\,pure\ liquide}} = \rho_2 \cdot \frac{S_{wet}}{V_{water}}$

If small pore I
If **fast exchange** **bulk** water and **surface** water.

→ **A α V_{water}**
→ **T_2 ≈ cste . V_{water}/S_{wet}**

NMR and MRI, a no destructive method time resolved.

Minispec Bruker
0,5 teslas
+ Gradient



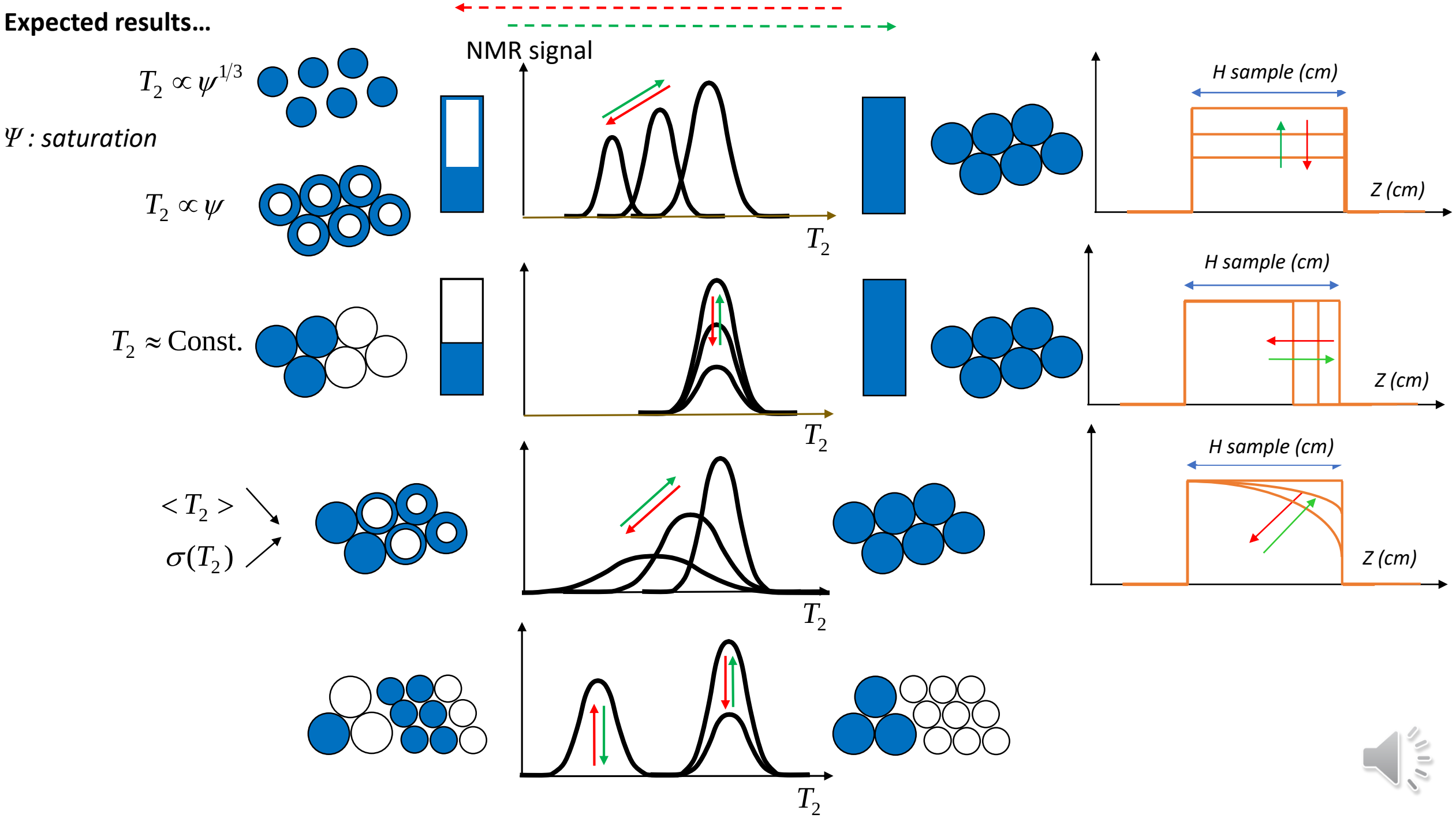
→ *Global information*

A(t), T2(t),
FWHM(t)

→ *Local information*

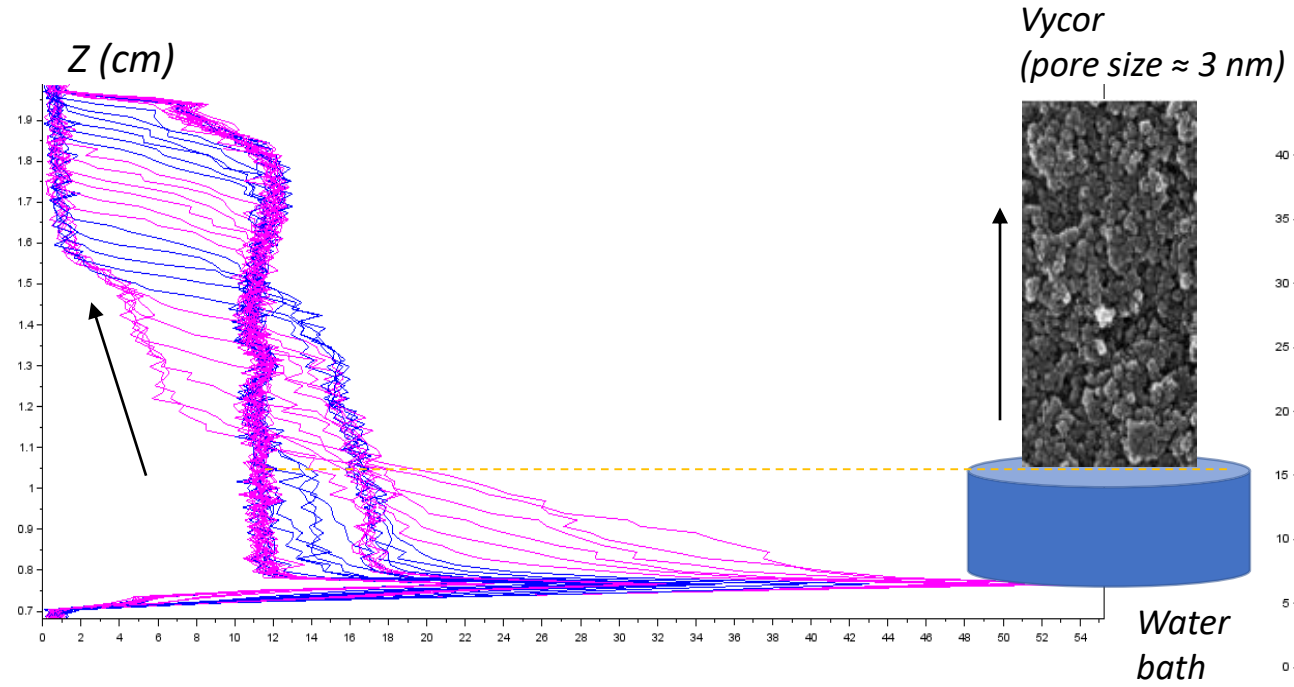
Ex : Drying of a piece of wood (≈ 1 cm³)

Expected results…

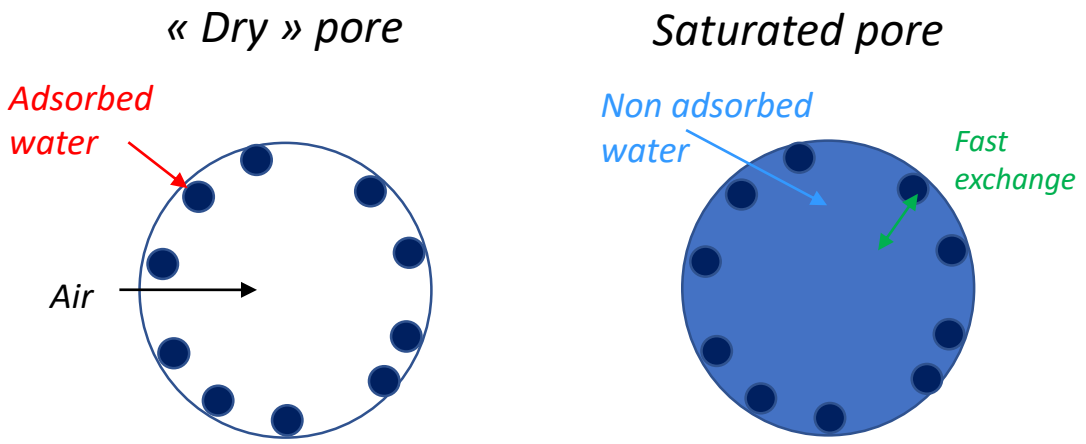


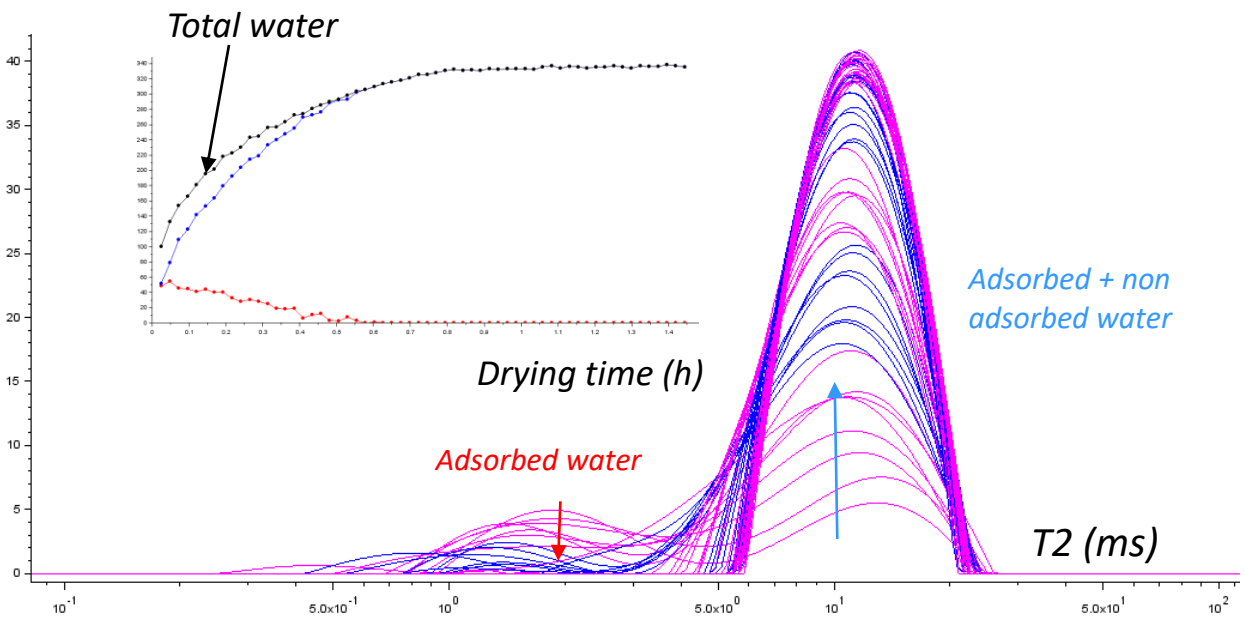
Vycor Imbibition

Philippe Coussot
Patrick Huber
Benjamin Maillet
Guido Dittrich
2022



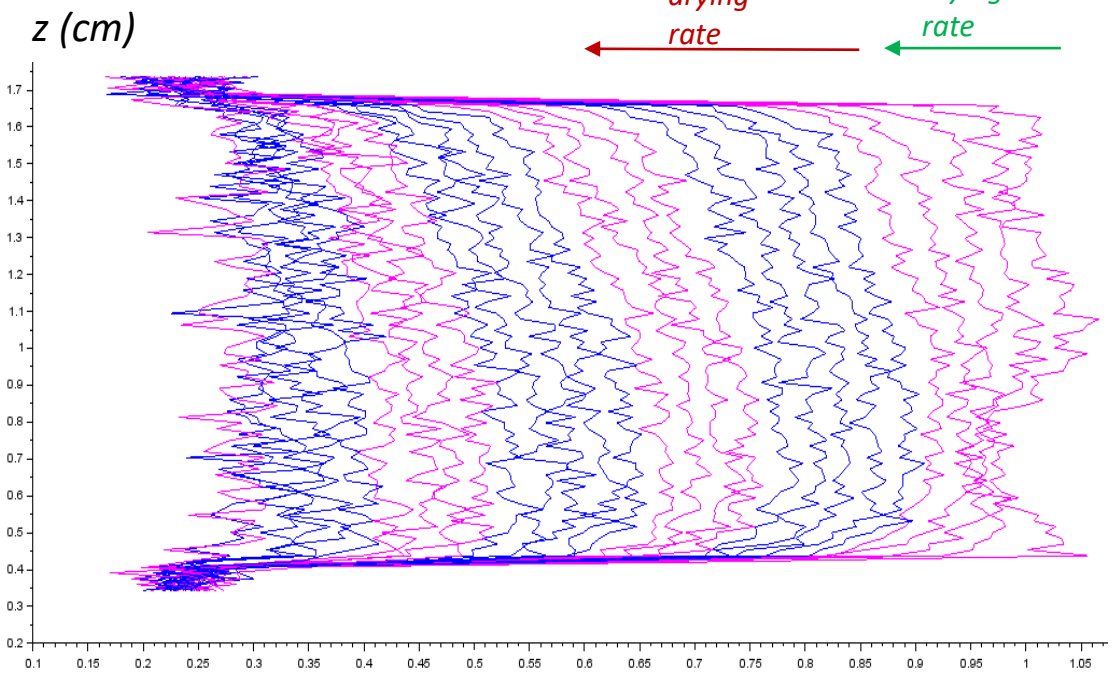
1D Profiles

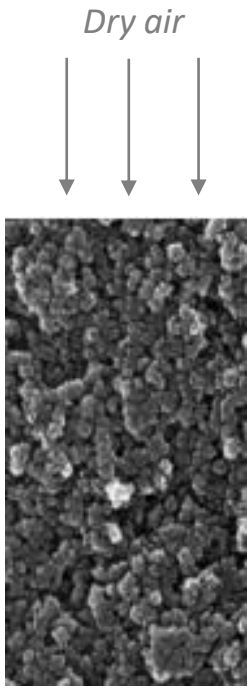


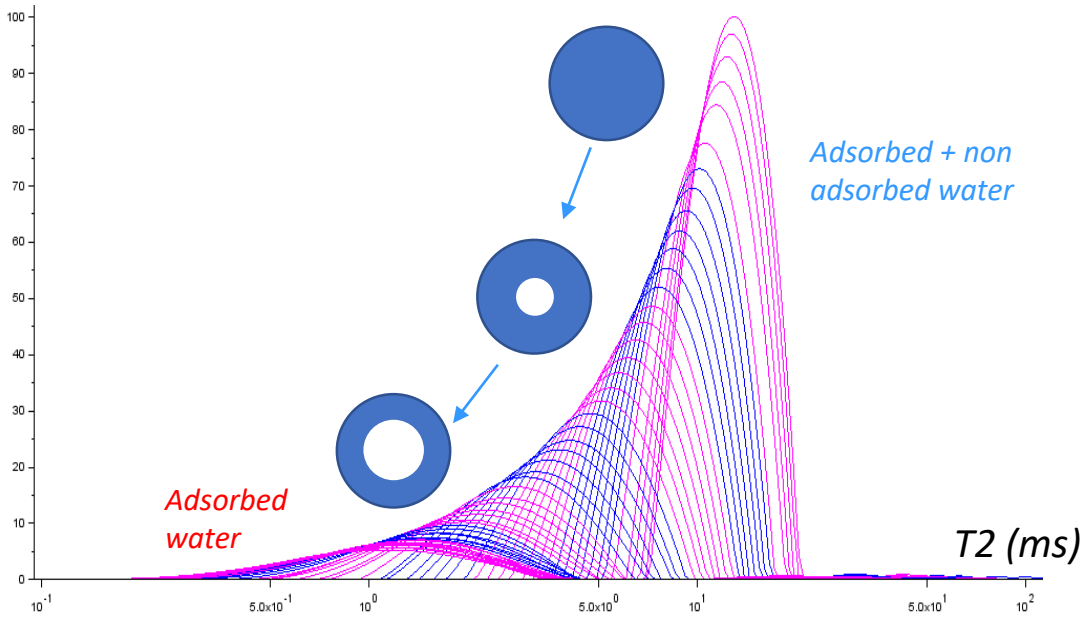


T2 distributions

Vycor drying

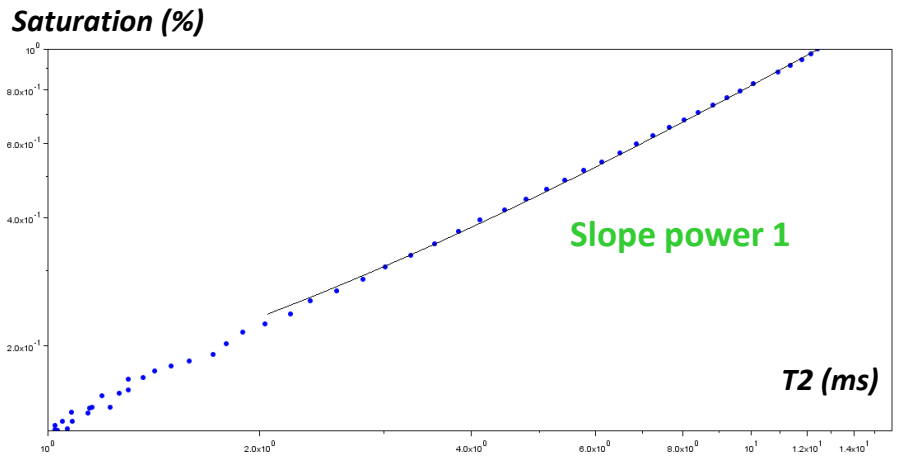






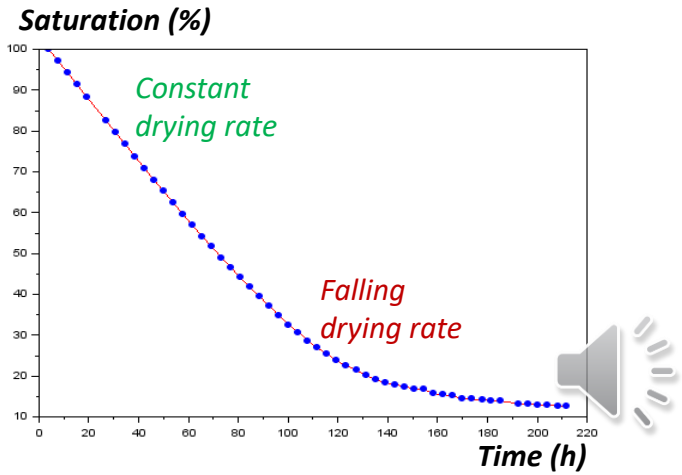
1D Profiles

T2 distributions

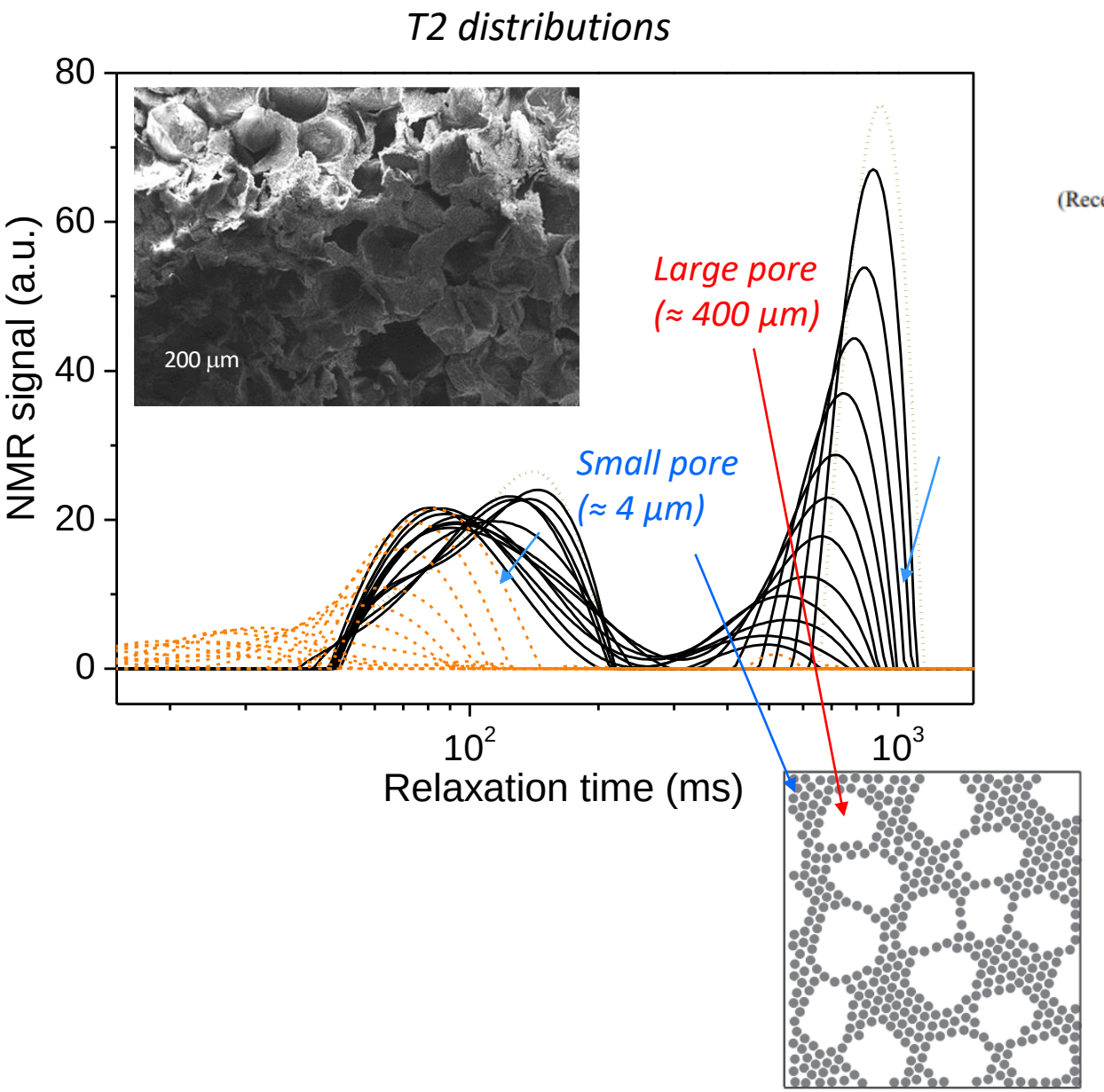


$T_2 \alpha a^3$ and $A \alpha a^3$

→ **S(wet) constant**



Biporous material drying



PHYSICAL REVIEW APPLIED **0**, XXXXXX (2020)

Drying of a Compressible Biporous Material

T. Lerouge,[1,2] B. Maillet,[1] D. Coutier-Murias,[1] D. Grande,[2] B. Le Droumaguet,[2] O. Pitois,[1] and P. Coussot[1,*]

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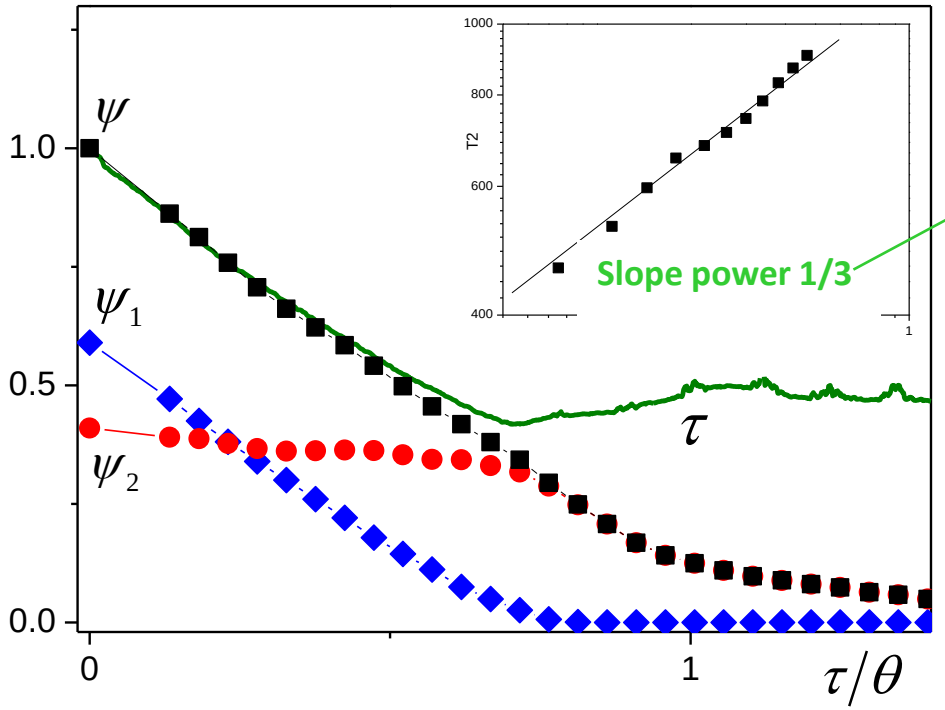


T_2 α a and
A α a^3
Isotropic contraction

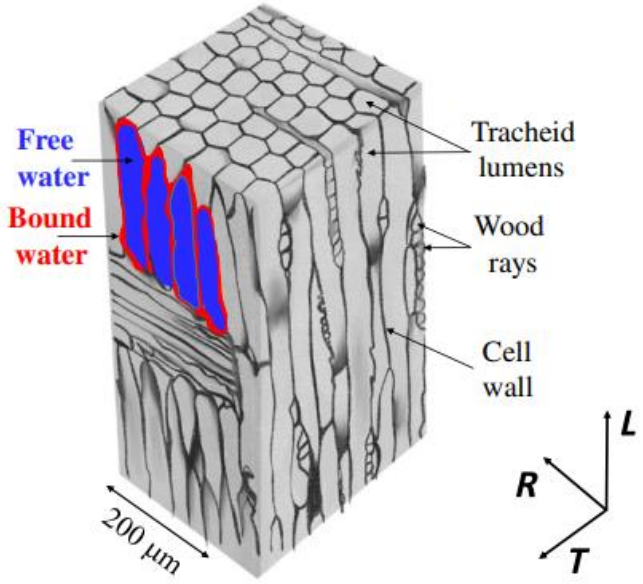
Recent publication (2022).

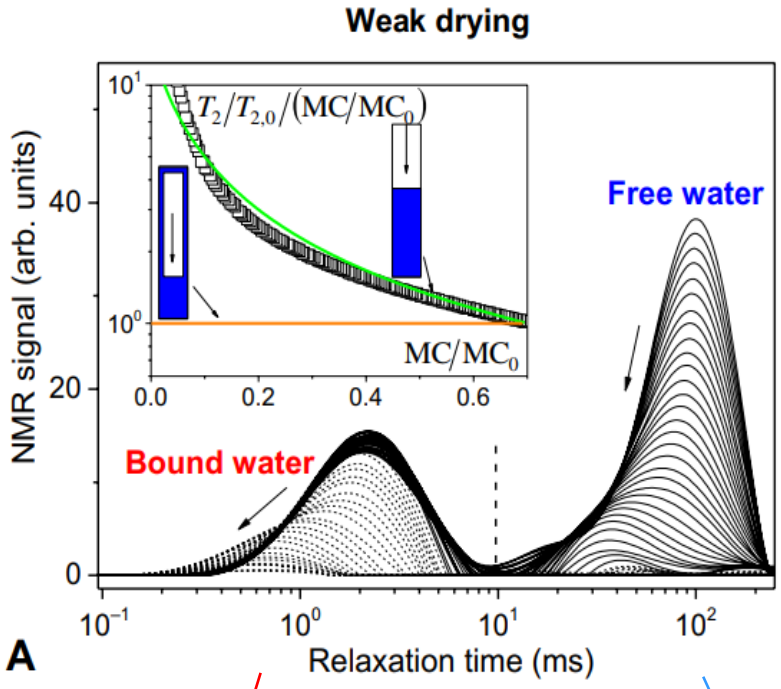
SCIENCE ADVANCES | RESEARCH ARTICLE

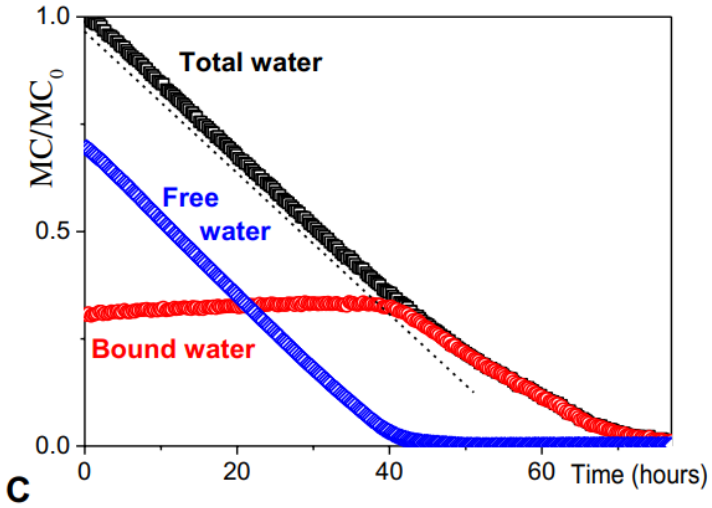
APPLIED PHYSICS

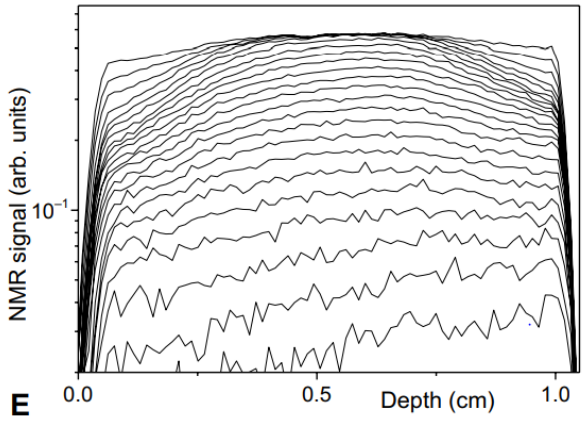
Two-step diffusion in cellular hygroscopic (vascular plant-like) materials

Marion Cocusse[1], Matteo Rosales[1], Benjamin Maillet[1], Rahima Sidi-Boulenouar[1], Elisa Julien[1,2], Sabine Caré[1], Philippe Coussot[1]*









T_2(bound water) decreases.

→ **In accordance with contraction**

T_2(free water) constant.

→ **Total dewetting for tracheids**

To conclude…

Dynamic relaxometry
→ Efficient and original methodology to describe fully liquid transfer.
→ Time resolved multiscale global and/or local analytic informations.

… thanks to T2 distributions (A(t), coupling T_2(t) – A(t), FWHM(t), for each population of water) and profiles.

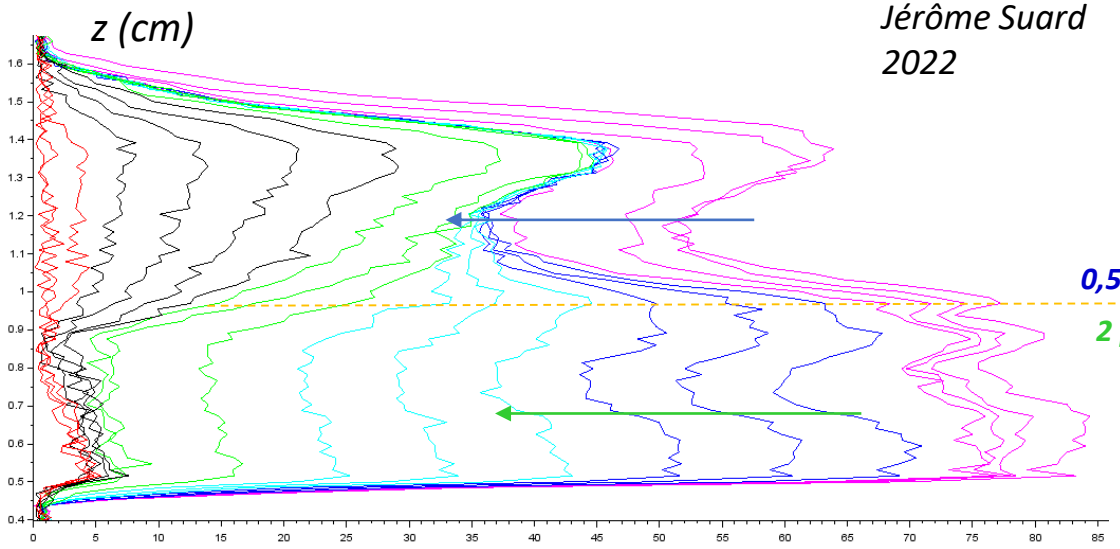
Extended to all the water or protonic liquid transfers.

Direct validation of transfer models allowed !

Thanks for your attention !

Drying of 2 layers glass bead packing

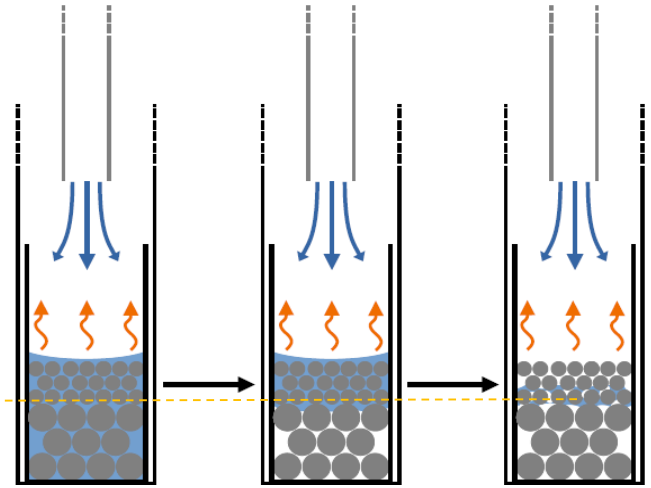
Philippe Coussot
Benjamin Maillet
Rahima Sidi-Boulenouar
Jérôme Suard
2022

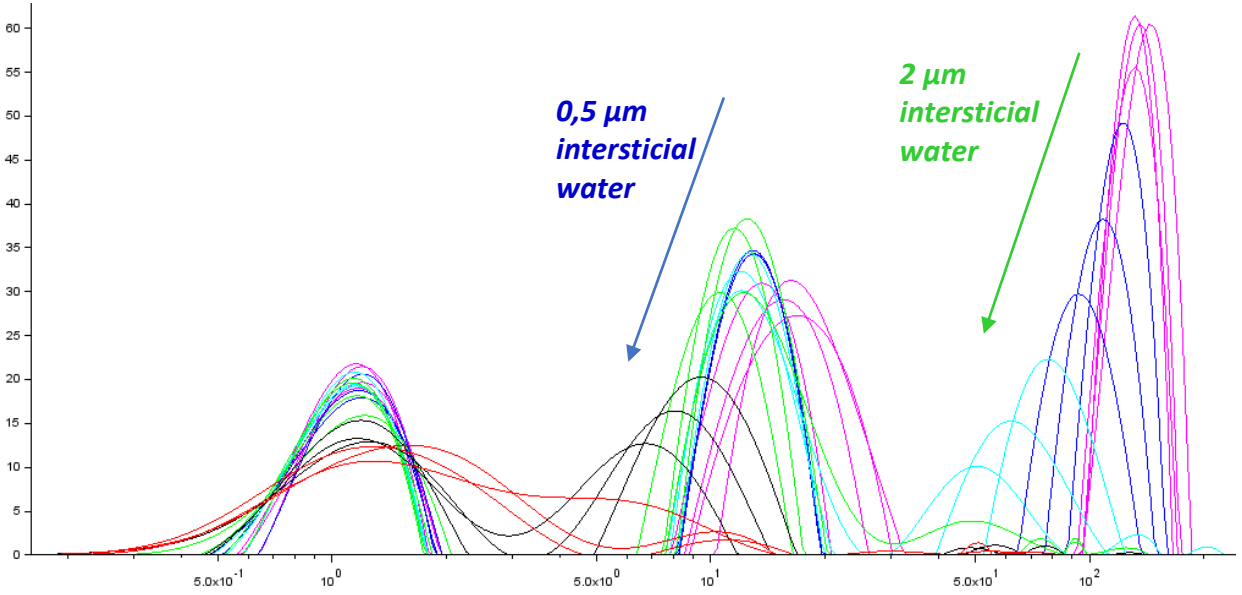


1D Profiles

0,5 µm intersticial water

2 µm interstical water





T2 (ms)

T2 distributions