

Restricted Diffusion of Polarized ^3He Gas in Silica Aerogels

[Contribution to LT23 – Extracts]

G. Tastevin and P.J. Nacher

Laboratoire Kastler Brossel
Ecole Normale Supérieure, Paris, F75005

<http://www.lkb.upmc.fr/polarisedhelium/polarised-helium-and-quantum-fluids/>

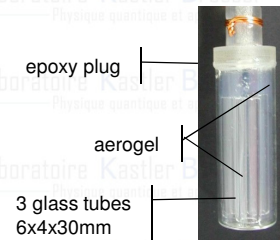
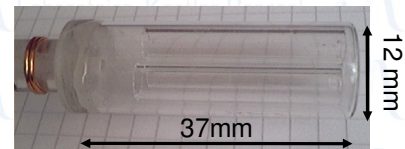
Other contributor: J. Choukeife (LKB)

Former collaborator: G. Guillot (U2R2M, Orsay)

Aerogel samples (97-98% porosity)

- *Home made, grown by M. Mulders*

* *sample M*



Porosity 98% Surface : 578 m²/g

- *Commercial, provided by G. Eska*

* *sample A*, from Airglass : 97%, 465 m²/g

* *samples J₁₋₄*, from Matsushita : 97%, 510 m²/g



Multiple spin-echo NMR technique (CPMG)

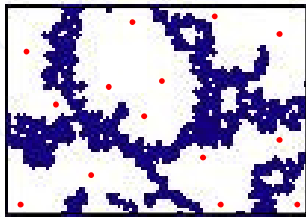
Echo attenuation induced by atomic diffusion :

In a controlled linear field gradient G , with echo time t_e

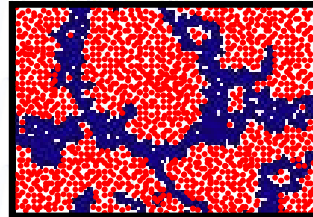
$$T_2^{\text{echo}} = \frac{12}{D(\gamma G t_e)^2}$$

D = diffusion coefficient in the medium

Operation with variable gas pressure (at 300K) :



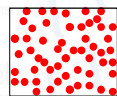
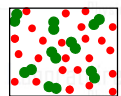
Diffusion is restricted by the aerogel.



He-He \approx He-aero. scattering?

$$\lambda_3(1 \text{ bar}) = 190 \text{ nm}$$

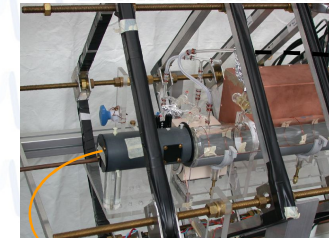
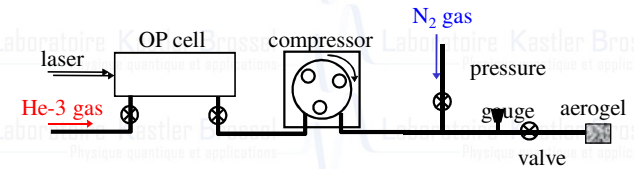
Using a (heavy) buffer gas :



$$P_{\text{eq}}^3 = P^3 + P_{N_2} \cdot \frac{D_{^3\text{He}}^0}{D_{N_2}^0} \times 2.5$$

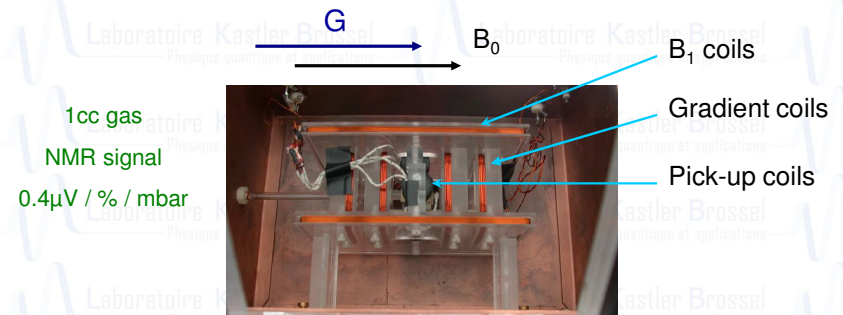
Experimental set-up

On-site ^3He hyperpolariser



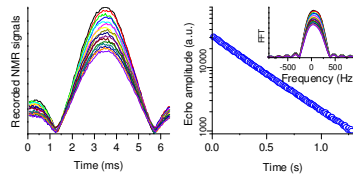
commercial fiber laser

... and very low field NMR unit



**Hyperpolarisation => good SNR at all pressures,
whatever the magnetic field intensity**

Sample M (0.1T)
JLTP 121 (2000) 773
MRI 19 (2001) 391

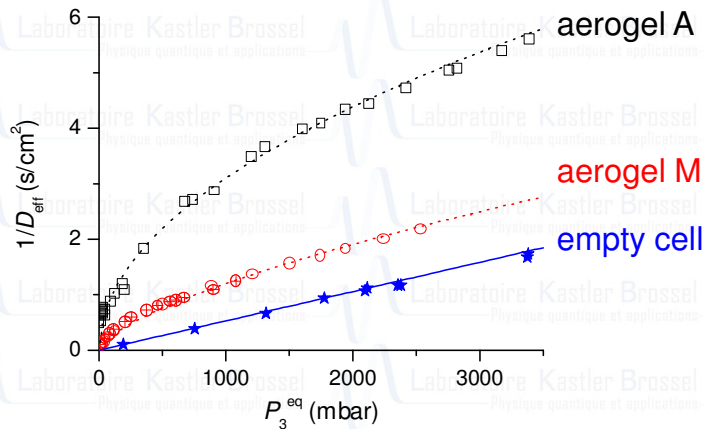


Monoexponential decay => fit gives

$$\frac{1}{D_{\text{eff}}} = \frac{(\gamma G t_e)^2 T_2^{\text{echo}}}{12}$$

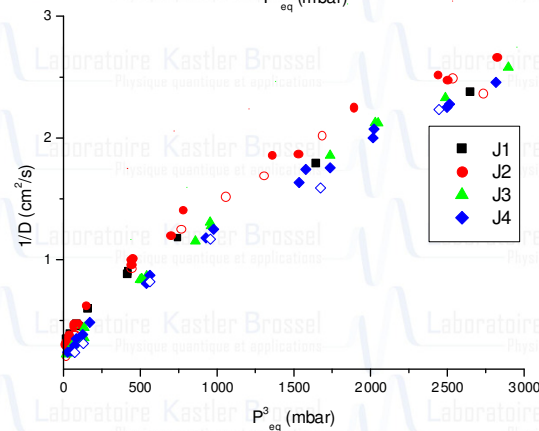
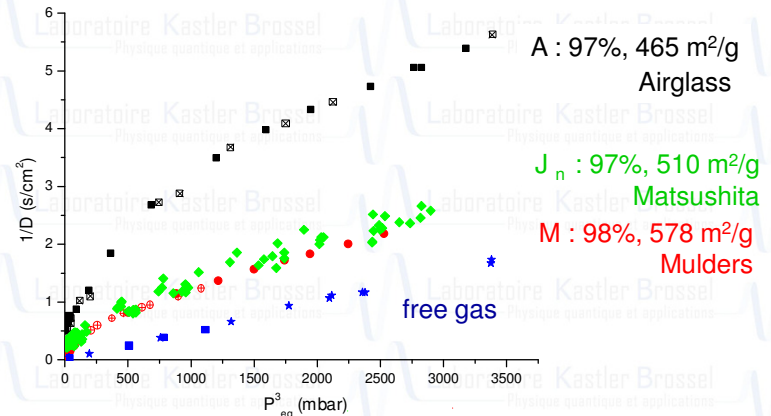
Results for samples M, A, J₂, T₃, J₄ tested at 2 mT

- polarisation lifetimes in aerogels exceed 3 minutes (6 min. on plastic)
- measurements with different combinations of G, t_e => same effective D
- T₂^{echo} : 0.05 - 1.5 s (2 to 150 echoes)



Aerogel M : QFS2000 results confirmed and extended

Results (cont ')



- Effective diffusion coefficients are not directly correlated to the nominal porosities of the aerogels.
- Minor differences are observed between the four Matsushita gels.

Conclusion

Sensitive method to non destructively probe the aerogels, with gas mfp $\approx 0.07 - 20 \mu\text{m}$.

Further systematic studies to be carried on, e.g. to improve the NMR spatial resolution.

..... So far :

* Specific features seem quite robust, despite the traumatizing strains endured.

* 1D measurements demonstrate significant differences between aerogels of different origins.

* Broad power-law distributions of mean free paths describe all samples.

NMR diffusion measurements probe the correlations between subsequent atomic displacements.

=> Distributions of locally correlated orientations of the silica strands with respect to the gradient axis??