# Topological defects and coherent magnetization precession of $^3He$ in aerogel

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**Abstract**

We have observed for the first time the formation of the region with Coherent Precession of Magnetization (CPM) in superfluid $^3He$ in aerogel covered by solid monolayers of $^4He$. The signal of CPM has been observed by pulsed NMR and by CW NMR. By playing with the magnetic field gradient we were able to distinguish the spatial position of the region of CPM as well as to determine the long scale inhomogenity of the order parameter. We have observed an evidence for existence of an enormous number of topological defects in superfluid $^3He$ in aerogel.

*Key words:* superfluid $^3He$; aerogel; topological defects; ultralow temperature

## 1. Introduction

The properties of superfluid $^3He$ in aerogel glass has been a subject which has attracted considerable interest over the past few years. The bulk superfluid $^3He$ is an absolute pure material, which indeed can display many different types of topological defects owing to the complex structure of the order parameter [1]. High density of topological defects in bulk $^3He$ can be created by fast cooling [2]. But even at slow cooling the order parameter of $^3He$ is always inhomogeneous due to the shape of the experimental cell, and it is likely that few topological defects are usually formed in the cell. The defects can be annealed by fast rotation, as it was shown by Helsinki experiments, or by nonlinear NMR, which can remove some types of magnetic defects [3]. Surprisingly, the existence of topological defects in $^3He$ in aerogel have never been discussed.

In Grenoble, we have made systematic studies of properties of superfluid and normal $^3He$ in aerogel with different coverages of $^4He$ monolayers. The experiments were done using a cylindrical cell with the axis parallel to the magnetic field of order 300 oe, at temperatures down to 200 $\mu$K. The results of our experiments will be published elsewhere. But in this article we are pointing out the two important observations. In order to explain our results we must suggest the B phase like ordering, which is not sensitive to $^4He$ coverage, but with high density of topological defects. And also we can report the formation of the domain with Coherent Precession of Magnetization by non-linear NMR.

## 2. Spatial inhomogenity of order parameter

There was many theoretical and experimental studies of $^3He$ in aerogel, where the $^3He$ was considered as a spatially homogeneous state. The properties of the NMR lines have usually been treated as common liquid plus solid $^3He$ single lines with broadening due to interactions within the solid and frequency shifts due to the superfluid $^3He$. The theoretical consideration was based on this simplified model. Exceptional may be only the work by the Stanford group, where the signal was treated as one radiated by a spatially oriented texture [4].

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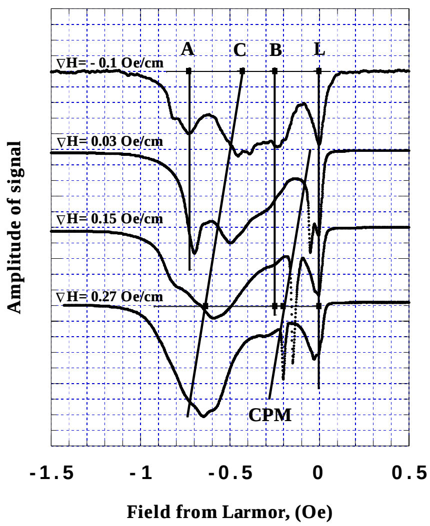


Fig. 1. The NMR lines of superfluid $^3He$ in aerogel covered by solid $^4He$, at 29 bar and 1.1 mK for different gradient of magnetic field. Line L corresponds to the Larmor frequency at the bottom of the cell. Lines A and B display the frequency shift, but its field gradient dependence also corresponds to the location at the bottom of the cell. Wide line C moves with gradient. Its average position corresponds to a location of about 4 mm up from the bottom. The same location corresponds to the signal of coherent precession of magnetization (CPM). CPM can be seen only at positive gradient, at high amplitude of radiofrequency magnetic field and sweep of field down, like well known HPD in the bulk $^3He$.

In our work in Grenoble we have found that the single line consideration is correct only for the region of temperatures above the superfluid transition in bulk. Below this temperature, the behavior of NMR signals became much more complicated. First of all, satellite lines appear [5], which we attribute to some regions inside the aerogel. The nature of these lines was unknown. Indeed these signals show that the $^3He$ inside aerogel at the region of temperatures between the superfluid transition in bulk and the superfluid transition in aerogel is NOT normal. Now we have seen also an anomaly of NMR broadening at this region of temperatures, which will be discussed elsewhere.

The superfluid transition of $^3He$ in aerogel manifests itself by the NMR frequency shift owing to the dipole-dipole interaction in superfluid liquid. But we have observed also an enormous inhomogeneous broadening of the NMR line, which is comparable with the average frequency shift. In reality, we have found a peculiar structure of the NMR line, which strongly depends on temperature. The frequency shift and broadening increase proportionally with replacing of solid $^3He$ by $^4He$. Furthermore, by playing with the gradient of magnetic field we have found the spatial nonequivalence of different peaks of NMR line. In Fig.1 are shown the NMR signals at four different gradients of magnetic field.

### 3. The region with coherent precession of magnetization

Particularly, one can find in Fig.1 the one very unusual peak, marked CPM. This peak appears only at relatively high amplitude of NMR excitation fields, at only one direction of the gradient of magnetic field and only when the magnetic field was swept down. The properties of this signal corresponds well to the basic properties of the so named Homogeneous Precession Domain in bulk $^3He$ [3]. The difference is only that the state, we have observed, has a relatively high dissipation, proportional to the amplitude of the signal. Interesting enough, the highly dissipative HPD signals can be found in the bulk $^3He$ at the presence of some kind of topological defects, named Spin-Mass vortex [6]. The magnetic gradient dependence shows the position of CPM inside the aerogel, on the distance about 4 mm from the bottom of the cell. It is likely that the coherent state appears somewhere at the region of flat order parameter near the Larmor frequency. But the spatial growing of this region is limited in our case by different types of topological defects.

Finally, we can suggest, that at the superfluid transition of $^3He$ in aerogel, different types of topological defects appear, and can not be annealed due to the pining with aerogel matter. This defects create many satellite lines, which leads to broadering of the NMR signal of $^3He$. More detailed articles will be published.

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