NMR in Superfluid Helium-3 in the Non-Hydrodynamic Regime

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This article is dedicated to the memory of Olli Lounasmaa, the physicist, who directed my scientific life along the path of superfluid $^3$He! In the article I review the results of experimental and theoretical studies of superfluid $^3$He spin dynamics at ultralow temperatures, where the density of the normal component is virtually zero. I describe our current understanding of the phenomena of catastrophic relaxation, NMR in the Landau field and the surface instability of homogeneous precession.

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1. OLLI LOUNASMAA

It is an honour for me to contribute to this volume dedicated to the memory of Olli Lounasmaa. For me, Olli Lounasmaa was one of the key individuals in the development of science during the second part of twentieth century. That was a century of both great discoveries and great contradictions. Olli once told me that his grandfathers came from opposite sides of the political spectrum in Finland. They disputed in parliament over the political future of Finland and the only time when they were not battling each other was during Olli’s birthdays.

The sundering of European civilization into East and West was the great tragedy of the twentieth century. Very few individuals managed to stand above and bridge this divide. Olli Lounasmaa was one of the first to puncture the scientific Iron Curtain. His Russian counterpart was the great Piotr Kapitza. At that time Yuriy Anufriev in Vasilii Peshkov’s laboratory in the Kapitza Institute had made the great advance of constructing the first Pomeranchuk cell. Even in the hostile conditions of the Brezhnev era,
Kapitza and Lounasmaa succeeded in bringing Anufriev to Lounasmaa’s laboratory to start a joint project of building a Pomeranchuk cell to be used in the then most modern dilution refrigerator. Despite these foresighted efforts, it was in fact Osheroff, Lee, and Richardson who were the first to succeed and as a result discovered $^3$He superfluidity.

The time of scientific contacts was beginning to emerge. Piotr Kapitza and Väimö Hovi were the first to establish formal scientific collaboration between Russia and Finland under the control of physicists rather than quasi-bureaucrats. On the basis of this collaboration, I was able to work in Hovi’s laboratory in Turku for three months in 1977. At that time I was a postgraduate student in the Kapitza Institute working on the non-linear and parametric excitation of nuclear spin echoes in antiferromagnets. On my way back to Moscow I had the chance to visit Olli Lounasmaa’s laboratory. That visit changed my scientific life.

Olli Lounasmaa was always very fast to grasp new ideas and to put them into practice. During my visit to Helsinki, Mikko Paalanen, then a student, explained the properties of NMR in $^3$He to me. They were very similar to those of NMR in antiferromagnets which I was working on. During a seminar I suggested applying the nonlinear NMR techniques to superfluid $^3$He and in particular parametric excitation. Lounasmaa’s reaction was immediate. He called Kapitza and asked him to send me to Helsinki for a two to three year period. While Olli Lounasmaa was a great scientific manager, Kapitza was too. His response was that my idea is very good, so good in fact that it did not merit being done somewhere else. Better to do it in Moscow in the Kapitza Institute. I was from the magnetic laboratory of professor A.S. Borovik-Romanov. Our laboratory had no experience in the field of ultra-low temperature. For me that meant preparing everything for a new nuclear demagnetization refrigerator, starting my work absolutely from zero. In compensation, I got a priori green light for all my orders to the workshop. Kapitza also promised to send me regularly to Olli Lounasmaa’s laboratory for two to three month visits.

Now, it is difficult for me to remember how many times I visited Helsinki. Altogether it amounted to more than two years. And what a remarkable time! The low temperature laboratory, as organized by Olli, had become definitely one of the best in the World. In the early years many foreign scientists worked there. Then the Russian-speaking influx began. That is the pattern in all low temperature laboratories in the World now, but Helsinki was 20 years in advance.

My next visit to Helsinki took place in 1979. It was the time of the construction of the refrigerator for the Finnish–Georgian joint project ROTA. The idea behind this was to repeat the classical Andronikashvili experiment