MICROKELVIN Transnational Access Project Report

1. General Information

Project number	AALTO08	
Project Title:	VORTEX MOTION AND DISSIPATION AT VERY LOW TEMPERATURES IN 3He-B	
Project Acronum:		
Lead scientist:[1]	**Title:**	**Dr.**
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	Last name:	**Walmsley**
	Birth date:	**16th June 1977**
	Research status/Position:	**Research Associate**
	New User:[2]	**Yes**
	Scientific Field:	**Superfluid hydrodynamics and turbulence**
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	Home institution is MICROKELVIN partner:	**Yes** ☐ **No X**
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[1] The lead scientist indicated here is expected to participate in the campaign as a user of the infrastructure.

[2] Indicate 'Yes' only if the user has never visited the infrastructure before this specific project, otherwise write 'No'.

2. Project information

Please, give a brief description of project objectives: (250 words max)	**SUPERFLUID DYNAMICS IN THE QUANTUM VACUUM LIMIT $T \to 0$** The characteristics of vortex flow in the $T \to 0$ temperature limit are of central interest in the quantum fluids research group at the University of Manchester and in the ROTA group of the Low Temperature Laboratory. In Manchester the measurements are concerned with superfluid ^{4}He while in Helsinki they are performed with ^{3}He-B. In both cases there are strong expectations that new progress in this area can be achieved at this time. To investigate the dynamic response of vortices in a rotating cryostat, the time-proven method is to record the spin up or spin down of the superfluid component after a sudden step-like change in the rotation velocity. The spin-down response has been found to be laminar down to temperatures ~ 0.20 Tc in a smooth-walled cylinder filled with 3He-B when surface pinning is absent. This result has been confirmed both experimentally and numerically in vortex filament calculations [1]. The spin-up process is more complicated because of the energy barriers and critical velocities associated with vortex formation. However, aside from this difficulty, vortex motion in the interior of the cylinder is also laminar during spin up. In contrast, if axial rotation symmetry is severely broken by obstructing the flow paths with measuring sensors located inside the measuring volume, such as quartz tuning fork oscillators, for instance, then the responses become turbulent. Interestingly it turns out that if one of the end plates of the cylinder is replaced by the AB interface, then both the spin-up and spin-down properties change and show more complicated behavior. So far only a first quick look at these changes has been carried out. To understand the dynamics at the AB interface, when vortices either extend through the interface or cover the interface as a vortex layer, we need to perform systematic measurements as a function of rotation velocity, temperature, and magnetic field. These studies are related to earlier work on the superfluid Kelvin-Helmholtz instability of the AB phase boundary [2], but the new spin-up/spin-down results should also be compared to similar measurements in the absence of the AB interface. Spin up and spin down in the present experimental setup generate also strong thermal signals which can be monitored and calibrated with quartz tuning fork sensors [3]. So far these measurements are few and there is no understanding how to explain the origin of these signals. This is a second area of problems where systematic measurements are required. These studies will hopefully teach us about quasiparticle kinetics and possibly about dissipation in vortex motion.
Technical description of work performed: (250 words max)	An extensive set of spin down and spin up measurements were performed using the ROTA rotating cryostat. The vortex dynamics in a cylindrical sample of superfluid 3He-B at 0.2 Tc were probed using a linear NMR spectrometer. The main focus was on observing how the spin down behaviour changed when one of the end plates of the cylinder was replaced by the AB interface. The measured NMR spectra following spin downs were

	compared to calibration spectra measured in the vortex-free state and also to calculated spectra with various different radial distributions of vorticity. The late-time behaviour after spin downs, both with and without the AB interface present, was investigated by using spin ups to measure the amount of remanent vorticity.
Project achievements (and difficulties encountered)**:**[5] (250 words max)	The behaviour of 3He-B in a cylindrical container following an impulsive spin down to rest was investigated at lower temperatures (0.2 Tc) than had previously been studied. The laminar regime was found to hold until at least 5000 s following a spin down. When the AB interface was present, the decay was observed to be much faster and the counterflow peak of the NMR spectrum was also noticeably different (when compared to solid-body rotation). The NMR spectra were found to be consistent with a simple model where there were no vortices in the central region of the cylinder but instead were concentrated in an outer shell. This is because the mutual friction in the A-phase is much higher than in the B-phase. The rapid radial motion of the A-phase vortices to the cylinder wall, following a spin down, created a vortex-free hollow in the B-phase at the AB interface. Differences in azimuthal motion between the two phases results in the vortices in the B-phase becoming helically twisted around the cylinder axis, pulling them towards the perimeter. The inhomogeneous twist produces reconnections and turbulence among the vortices, results in a rapid spin down. Subsequent spin ups were much slower compared to the case where there was no AB boundary present due to the almost complete absence of remanent vortices.
Expected publications and dates:	▪ **Conference proceedings 2010/11** ▪ ▪
Submission date of user group questionnaire:	11th June 2010

Completed Project Reports should be returned to MICROKELVIN Management Office, Katariina Toivonen, Fax: +358 9 4512969).