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European Microkelvin Collaboration

CAPACITIES

Report on the Transnational Access Activity carried out within MICROKELVIN

The eligibility of transnational access to a MICROKELVIN TA site implies the submission of the following:

1) The Certification of visit

The form "Certification of visit" must be completed and signed by the access provider in charge of the infrastructure and the leader of the project.

2) A TA project report

The form for the TA project report is contained within this document. It should be completed after project end by the group leader of the project. You must respect the limited number of words specified, longer descriptions will be rejected. Figures/tables may be attached at the end of the document. The document must be submitted in an editable format (doc, rtf).

3) A User group questionnaire

To enable the Commission to evaluate the Research Infrastructures Action, to monitor the individual contracts, and to improve the services provided to the scientific community, each project leader of a user-project supported under an EC Research Infrastructure contract is requested to complete a "user group questionnaire". The questionnaire must be submitted once by each user group to the Commission as soon as the experiments on the infrastructure come to end.

The user group questionnaire is not part of this document and must be completed on-line. It is accessible at:

http://cordis.europa.eu/fp7/capacities/questionnaire_en.html.

► **Please note that any publications resulting from work carried out under the MICROKELVIN TA activity must acknowledge the support of the European Community:**

"The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 228464 (MICROKELVIN)."

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MICROKELVIN Transnational Access Project Report

1. General information

Project number:	**AALTO 38**	
Project Title:	**Graphene and superfluid 3He**	
Lead scientist:[1]	**Title:**	Professor
	First name:	Mikhail
	Last name:	Katsnelson
	Home institution:	Radboud University of Nijmegen
Host scientist:[2]	**Title:**	Dr.
	First name:	Grigory
	Last name:	Volovik
	Home institution:	Lounasmaa Laboratory, Aalto University
Project scientist:[3]	**Title:**	professor
	First name:	Mikhail
	Last name:	Katsnelson
	Birth date:	
	Passport number:	
	Research status/Position:	
	New User:[4]	
	Scientific Field:	physics of strongly correlated systems
	Home institution:	Radboud University of Nijmegen
	Is your home institution MICROKELVIN partner?	no
	Business address:	
	Street:	Heijendaalseweg 135
	PO Box:	
	City:	Nijmegen
	Zip/Postal Code:	6525AJ
	Country:	The Netherlands
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	E-mail:	M.Katsnelson@science.ru.nl

[1] The lead scientist indicated here is expected to participate in the campaign as a user of the infrastructure.

[2] The host scientist is supervising the work of the visiting project scientist at the infrastructure.

[3] THE PROJECT SCIENTIST IS THE PERSON WHO WILL BE VISITING THE INFRASTRUCTURE.

[4] 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)	This project is devoted to the study of those properties which are common to both superfluid 3He and graphene. The plan is to exploit experiments with graphene in the superfluid 3He environment and to prepare for such efforts during this short 6-day visit. Both systems are topological materials. They contain topologically protected massless fermions: 2+1 Dirac fermions in graphene ; 3+1 Weyl fermions in bulk 3He-A ; 2+1 Majorana fermions on the surface of 3He-B ; 1+1 Majorana fermions in the cores of quantized 3He-B vortices. In both systems relativistic quantum fields and gravity emerge with all the related phenomena, such as chiral anomaly, Hawking-Unruh effects, and Schwinger pair production in electric field. The combination of graphene and superfluid 3He makes it possible to study the interplay of the two topological materials plus the new effects, which emerge, when these materials are combined, Experiments on graphene immersed in superfluid 3He may include the following: measurement of the spin Josephson effect in 3He-B due to the spin current through the graphene layer; the exploitation of oscillating graphene for the observation of Majorana fermions on the graphene 3He-B boundary in superfluid 3He-B; investigation of the properties of graphene in the superfluid environment at ultralow temperatures under different 3He-B conditions (in the presence of rotation, superflow, quantized vortices, external magnetic fields, magnon Bose-Einstein condensate, etc.) which are all unique in condensed matter physics.
Technical description of work performed: (250 words max)	We elaborated several different directions into which the experimental work can be directed. These include: - Theoretical and experimental investigation of possible exciton condensates of 3He atoms across a graphene sheet (in the absence of tunnelling of atoms through the sheet), when the broken symmetry is U(1) x U(1). - The study of 3He-B Majorana fermions on the graphene sheet and their interaction across the sheet. There should be present an interaction of the spins of Majorana fermions with magnetic impurities localized on the graphene sheet, as considered for edge states in topological insulators. This may give a measurable mass to Majorana fermions. The interaction between Majorana particles can be transmitted by ripples in the sheet, which play the same role as relativistic gravity (exchange by gravitons), as follows from the momentum space topology which predicts an effective gravity field in terms of the effective tetrad (zweibein). - Another possible channel for the interaction between Majorana fermions is direct spin-spin interaction and the interaction with Dirac fermions of graphene. - The study of spin currents across graphene using the magnon BEC

	in superfluid 3He-B. There can be different channels of coupling the spin degrees of freedom across the graphene sheet: the electronic subsystem of graphene (Dirac fermions); an adsorbed magnetic layer of solid 3He; magnons; ripplons; or the direct dipole interaction of 3He spins across the graphene sheet. - Oscillating graphene membrane, driven electrically or magnetically: One should study the renormalization of the membrane mass by the associated hydrodynamic mass of the superfluid. - Other studies of the 3He-B and 3He-A superfluids: modification of the ripplon spectrum due to the superfluid hydrodynamics, the contribution of Majorana fermions on the surface of 3He-B to the frequency shift and the dissipation, and the effect of orbital viscosity in 3He-A due to Majorana fermions in the bulk. - Dynamical Casimir effect: Membrane oscillations as a time dependent metric for Majorana fermions. This may lead to an analogue of pair creation in the expanding Universe. We shall compare this phenomenon with the current experiments of the decay of the magnon BEC owing to oscillations of the free surface. Possibly this may reveal a common mechanism for the creation of Majorana fermions by oscillating fields. - Study of heat currents across graphene, including the propagation of 3He quasiparticles across graphene. - Study of low dimensional magnetism of graphene, the effect of the dipole interaction on the magnetic long-range order; possible ferromagnetism of doped graphene at ultralow temperatures; electric dipole moments localized on graphene.
Project achievements (and difficulties encountered):[5] (250 words max)	The physics of graphene and the physics of the superfluid phases of 3He have many common features. Both systems are topological materials where quasiparticles behave as relativistic Majorana or Dirac fermions. We have identified the regimes where these features are overlapping. This will allow us to use graphene for the study of superfluid 3He, or vice versa, to use superfluid 3He for the study of graphene, while the combination of the topological effects can be used to study the physics of the topological quantum vacuum.
Expected publications and dates:	
Submission date of user group questionnaire:	2.9.2013

Completed Project Reports should be returned to MICROKELVIN Management Office

(Mari.Kaarni@aalto.fi, Fax: +358 9 47022969).

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CERTIFICATION OF VISIT

at MICROKELVIN Transnational Access Site

I herewith confirm that the following project was carried out at our Transnational Access Site *(Aalto University)*

in the context of MICROKELVIN Transnational Access:

(Studies of graphene and superfluid 3He).

The amount of access[1] delivered to the project group (project users) is as follows:

	Participant name	Duration of stay (start – end date)	Amount of access[2]
Project leader:	M. Katsnelson	11.08.13-17.08.13	7
Project user 1:	M. Katsnelson	11.08.13-17.08.13	
Project user 2:			
Project user ...:[3]			
Total amount of access delivered to project group:			**7**

Location and date

Otaniemi, 16.08.2013

G. Volovik

Signature of access provider

G. Volovik

Location and date

Otaniemi, 16.08.2013

Signature of project leader

M. KATSNELSON

Completed Certification of Visit should be returned to MICROKELVIN Management Office (mari.kaarni@aalto.fi, fax: +358 9 47022969)

[1] TKK Helsinki, CNRS Grenoble, or Lancaster University

[2] The amount of access is defined as the time, in days, spent by the user at the infrastructure for this project, including weekends and public holidays (e.g., a scientist who spent 5 days at the infrastructure must indicate '5'). The total amount of access of the project group is the sum of access days of each project user.