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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 37**	
Project Title:	**Study of graphene in superfluid 3He**	
Lead scientist:[1]	**Title:**	Dr.
	First name:	Gil
	Last name:	Jannes
	Home institution:	Universidad Politecnica de Valencia - Nanophotonics Technology Center
Host scientist:[2]	**Title:**	Dr.
	First name:	Grigory
	Last name:	Volovik
	Home institution:	Lounasmaa Laboratory, Aalto University
Project scientist:[3]	**Title:**	professor
	First name:	Gil
	Last name:	Jannes
	Birth date:	
	Passport number:	
	Research status/Position:	
	New User:[4]	
	Scientific Field:	Quantum gravity effects
	Home institution:	Universidad Politecnica de Valencia - Nanophotonics Technology Center
	Is your home institution MICROKELVIN partner?	no
	Business address:	
	Street:	Camino de Vera, s/n, Building 8F | 2nd Floor
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	Telephone:	+34 674 537 195
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	E-mail:	gil.jannes@gmail.com

[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 the topological properties of superfluid 3He and graphene which are common to both of these systems. 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 the 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 these properties in these two topological materials plus the new effects, which emerge, when these materials are combined, Our possible 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 have discussed in particular that group of fundamental problems which are related to rotation and which can be studied combining the physics of graphene and the physics of the superfluid phases of 3He. These include: • Mach's principle applied to rotation. Mach's principle is one of the iconic principles underlying general relativity. Applied to rotation, it poses the question whether it makes sense to speak of an overall rotational motion of the universe, and whether a local observer would be able to detect such a hypothetic overall rotational motion. If matter and gravitation as we observe them emerge in the low-energy limit from the quantum vacuum, then Mach's principle (in the sense that an overall rotation of the universe is not detectable) can be correct. The key point is that one needs to take the quantum vacuum, and in particular the rotation of the vacuum, into account. This can be studied in superfluid and graphene, where the role of the quantum vacuum is played by the ground state of the system, and the role of matter is played by the excitations, the Majorana and Dirac fermions. The rotation is provided by the ROTA cryostat operating at sub-mK temperatures.

	• Closed time like curves. The existence of such curves in general relativity (GR) is a debated issue. The GR community poses the question, whether it is possible to simulate such hypothetical objects in condensed matter. The possible route is to use the effective metric simulated by different types of quantum vortices created in the superfluid phases of 3He under rotation, and to use the effective metric experienced by Dirac fermions in graphene for the simulation of Goedel's rotating Universe.
Project achievements (and difficulties encountered)**:**[5] (250 words max)	The physics of graphene and of the superfluid phases of 3He have many common features. Both systems are topological materials where quasiparticles behave as relativistic Majorana or Dirac fermions, which experience effective gravity in terms of tetrad field and metric. This makes it possible to use graphene and superfluid 3He for the simulation of the rotating relativistic quantum vacuum.
Expected publications and dates:	
Submission date of user group questionnaire:	7.9.2013

Completed Project Reports should be returned to MICROKELVIN Management Office

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

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CAPACITIES

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:

(Study of graphene in superfluid 3He, AALTO37).

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:	G. Jannes	16.06-21.06; 02.09.13-06.09.13	11
Project user 1:	G. Jannes	16.06-21.06; 02.09.13-06.09.13	11
Project user 2:			
Project user ...:[3]			
Total amount of access delivered to project group:			**11**

Location and date

Otaniemi, 06.09.2013

G. Volovik

Signature of access provider

G. Volovik

Location and date

Otaniemi, 06.09.2013

Signature of project leader

GIL JANNES

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