welcome to the
European Microkelvin Collaboration

CAPACITIES

Application Form for MICROKELVIN Transnational Access Project

1. General Information

Project number:	**Lancaster 18**	
Project Title:	**The superfluid 3He AB interface; friction and orbital viscosity**	
Lead scientist:[1]	**Title:**	Dr.
	First name:	Manuel
	Last name:	Arrayas
	Home institution:	Universidad Rey Juan Carlos
Host scientist:[2]	**Title:**	Dr.
	First name:	Richard
	Last name:	Haley
	Home institution:	Lancaster University
Project scientist:[3]	**Title:**	Dr.
	First name:	Manuel
	Last name:	Arrayás
	Birth date:	21/07/1972
	Passport number:	AC899408
	Research status/Position:	Reader
	New User:[4]	No
	Scientific Field:	Low temperature plasma physics
	Home institution:	Universidad Rey Juan Carlos
	Is your home institution MICROKELVIN partner?	No
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	E-mail:	manuel.arrayas@urjc.es
	Curriculum vitae (18 lines max): 1. Teaching Assistant, Lancaster University (UK), 1998-1999. 2. Postdoc, Instituut-Lorentz, Universiteit Leiden (NL), 1999-2001. 3. Researcher, Centrum voor Wiskunde en Informatica (NL), 1999-2001. 4. Prof. Asociado Tipo 2, Universidad Rey Juan Carlos, 2001-2002., Prof. Asociado Tipo 3, Universidad Rey Juan Carlos, 2002-2003. Prof. Contratado Doctor, Universidad Rey Juan Carlos, 2003-2009. RESEARCH VISITS: • Faculty of Mathematics, Physics and Natural Sciences, Università di Pisa, Italy, 4 weeks, 1999. Institut für Physik, Universität Potsdam, Germany, 2 weeks, 2004. Engineering Faculty, University of Ljubljana, Slovenia, 2 weeks, 2004. Low temperature Lab, Helsinki University of Technology, Finland, 2 weeks, 2008. Innsbrucker Experimentelle Plasmaphysikgruppe,	

[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 working as a visiting researcher at the infrastructure.

	Innsbruck, Austria, 1 week, 2008. Department of Physics and Astronomy, University of British Columbia, Canada, 4 weeks, 2008. Physics Department, Lancaster University, U.K. 6 weeks, 2010.		
	Five most recent publications:		
	1. Onset of treelike patterns in negative streamers. M. Arrayás, M. A. Fontelos and U. Kindelán. Phys. Rev. E 86, 066407 (2012).		
	2. Quantum Brownian motion in a periodic potential: The path integral for a super-Ohmic bath. M. Arrayás. FNL 11, 124006 (2012).		
	3. Exchange of helicity in a knotted electromagnetic field. M. Arrayás and J.L. Trueba. Ann. Phys. (Berlin), (2011).		
	4. Motion of charged particles in a knotted electromagnetic field M. Arrayás and J.L. Trueba. J. Phys. A: Math. Theor. 43, 235401 (2010).		
	5. Contour dynamics model for electric discharges. M. Arrayás, M. A. Fontelos and C. Jiménez. Phys. Rev. E 81, 035401 (2010).		
Other participating scientists:[3]	**Name:**	**Position:**	**New User:**[2]
	1-		

[3] Please list all participating user group members. Expand the table, if necessary.

2. Project Information

Name of host infrastructure:	Ultra Low Temperature Laboratory, University of Lancaster, Lancaster, United Kingdom			
Access provider / Infrastructure Director:	**Name:** Prof. S.N. Fisher Prof. G.R. Pickett		**E-mail address:** s.fisher@lancaster.ac.uk g.pickett@lancaster.ac.uk	
Planned project dates:	**Start date:**	**12/8/13**	**Completion date:**	**6/9/13**

Project description (12 lines max):

The analogies between the order parameter of superfluid helium-3 and those describing other fundamental systems allow us to use superfluid helium-3 as a model system to study a broad range of phenomena. For instance the symmetry-breaking phase transitions to the superfluid provide a test-bed for studying transitions in the quantum vacuum state of the evolving early Universe. The order parameters of the superfluid A and B condensates are analogous to quantum vacuum states existing in 3 dimensions as a 3-brane. The highly ordered 2D interface between the A and B phases is then a 2-brane. Now experimental work is in progress to measure the properties of this interface, with a focus on its dynamical behaviour. Dr Arrayas is experienced in studying and simulating the dynamics of interfaces and has been assessing various instability modes.

During Dr Arrayas' last visit we realised that friction on the moving interface must be important in impeding the growth of instabilities. This led us to examine the unexplained non-linear dissipation observed for an oscillating interface. Dr Arrayas is able to model the effects of dissipation by numerical simulations which he developed during his previous visit. Towards the end of his last visit we had a breakthrough. The motion of the interface must induce changes in the local texture either side of the interface. These changes will be damped by orbital viscosity. Our preliminary crude estimates indicate that this could be a dominant mechanism for the observed dissipation.

We already have a general theory of orbital viscosity, but we now need to apply this to texture changes induced by the moving AB interface. This is quite a complex problem which we believe is crucial to understanding the interface dynamics at low temperatures. Given his background, Dr Arrayas is ideally suited to work on this. Dr Arrayas has used 82 days of his 90 day Microkelvin visitor allocation for developing numerical simulations and for investigating instabilities of the interface. The current proposal, which focusses on orbital viscosity, is complimentary but otherwise quite distinct from his earlier work and should therefore be considered as a separate project. To make significant progress towards this new goal, we request a 4 week visit for Dr Arrayas.

Scientific objectives of the project (12 lines max):

Our primary objective is to include orbital viscosity in our model for the moving interface and use it to describe the subsequent dissipation. This is of crucial importance to understand the interface dynamics at low temperatures. We have measurements of the dissipation caused by an oscillating interface that we have been unable to explain, even qualitatively. We believe that orbital viscosity could offer a solution to this. We will first concentrate on using orbital viscosity to calculate the dissipation from a changing texture in the distorted B-phase. We will then apply this to simple model textures such as the flare-out texture on the B-phase side of the interface. The resulting dissipation will then feed back into the equation of motion governing the interface dynamics. In principle we can also study the effect on non-ideal textures and textural defects either side of the interface. We can compare this with existing experimental data. We will also apply these ideas to calculate the velocity of a freely moving interface. This secondary objective is important as the free interface moves so fast in our experiments that we have only been able to put a lower limit on its speed owing to limitations in our measurements technique. Knowing the velocity impacts on assessing the stability of the moving interface and therefore on the likelihood of leaving topological textural defects in its wake.

Technical description of work to be performed (20 lines max):

In our experimental arrangement the texture of the A and B phase order parameters is influenced by the interface, and bends by 90 degrees from its direction in bulk. As the interface moves, the texture of the surrounding A and B phase must bend and realign to accommodate it. Previous attempts by Leggett and

Yip, and Kopnin, to model the friction on a moving interface did not include effects of the bending texture, and therefore ignored orbital viscosity, leading to estimates of dissipation that are much lower than what we have measured experimentally.

With Dr Arrayas, we will model the moving interface and the concomitant bending of the texture. We will apply ideas of orbital viscosity to calculate the subsequent dissipation, and hence friction on the moving interface. We will compare the model calculations to the existing measurements of the anomalous drag on an oscillating interface. This should provide us with a better, more complete, understanding of interface dynamics at low temperatures. We will then use this model to make estimates of the speed of a freely moving interface limited by friction. It may also be possible to develop a model to calculate the effects of textural defects in the bulk and on the walls of the experimental container. Understanding the interface dynamics will play a key role in understanding the formation of defects by rapidly moving and/or colliding interfaces, which will also impact on understanding possible cosmological defect formation in the early universe.

3. Joint Proposals / Funding

Is this project in collaboration with other (concurrent) projects at the infrastructure?	☐ **No** ☐
If yes, please specify:	

Is this proposal submitted to any funding programmes?	☐ **No** ☐
If yes, please specify:	

The completed Application Form should be submitted to MICROKELVIN Management Office (**laitila@neuro.hut.fi**, fax +358-9-47022969)