welcome to the

European Microkelvin Collaboration

CAPACITIES

# Application Form for MICROKELVIN Transnational Access Project

## 1. General Information

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|---|---|---|
| **Project number:** | Lancs10 | |
| **Project Title:** | **The superfluid 3He AB interface; dynamics and instability modes** | |
| **Lead scientist:**[1] | **Title:** | Dr |
| | **First name:** | Manuel |
| | **Last name:** | Arrayás |
| | **Birth date:** | 21/07/1972 |
| | **Passport number:** | AC899408 |
| | **Research status/Position:** | Reader |
| | **New User:**[2] | No |
| | **Scientific Field:** | Low temperature plasma physics |
| | **Home institution:** | Universidad Rey Juan Carlos |
| | **Is your home institution MICROKELVIN partner?** | No |
| | **Business address:** | |
| | Street: | Camino del Molino s/n, Edif. Biblioteca, Desp. 008 |
| | PO Box: | |
| | City: | Fuenlabrada, Madrid |
| | Zip/Postal Code: | 29843 |
| | Country: | Spain |
| | Telephone: | +34 914888460 |
| | Fax: | |
| | 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. <br><br> RESEARCH VISITS: <br> • 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, 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 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'.

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|---|---|---|---|
| | 1.Exchange of helicity in a knotted electromagnetic field. M. Arrayás and J.L. Trueba. Ann. Phys. (Berlin), (2011). | | |
| | 2. Motion of charged particles in a knotted electromagnetic field M. Arrayás and J.L. Trueba. J. Phys. A: Math. Theor. 43, 235401 (2010). | | |
| | 3. Contour dynamics model for electric discharges. M. Arrayás, M. A. Fontelos and C. Jiménez. Phys. Rev. E 81, 035401 (2010). | | |
| | 4. Vorticity field, helicity integral and persistence of entanglement in reaction-diffusion systems. J.L. Trueba, M. Arrayás. J. Phys. A: Math. Theor. 42, 282001 (2009). | | |
| | 5. Comment on Mechanism of Branching in Negative Ionization Fronts - Reply. M. Arrayás, M. A. Fontelos and J.L. Trueba. Phys. Rev. Lett. 101, 139502 (2008). | | |
| **Other participating scientists:**[3] | **Name:** | **Position:** | **New User:**[2] |
| | 1- | | |
| | 2- | | |
| | 3- | | |

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

## 2. Project Information

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| **Name of host infrastructure:** | Ultra Low Temperature Laboratory, University of Lancaster, Lancaster, United Kingdom | | | |
| **Access provider / Infrastructure Director:** | **Name:**<br>Prof. S.N. Fisher<br>Prof. G.R. Pickett | | **E-mail address:**<br>s.fisher@lancaster.ac.uk<br>g.pickett@lancaster.ac.uk | |
| | | | | |
| **Planned project dates:** | **Start date:** | **22/8/12** | **Completion date:** | **25/9/12** |

**Project description (12 lines max):**

Superfluid helium-3 experiments can provide analogues for cosmological processes, allowing for the study of fundamental physical processes in the laboratory. The symmetry-breaking phase transitions of the superfluid provide a test-bed for those undergone by the evolving Universe after the Big Bang. One of the MICROKELVIN goals is to investigate the properties of condensate-condensate phase boundaries as analogue branes. The superfluid AB phase interface is a highly ordered 2D surface, or 2-brane, embedded in a 3-brane comprising the underlying quantum vacuum states of the A and B condensates. At Lancaster, colliding 2 of these A-B branes together has been shown to create topological defects of lower dimension, in analogy with the creation of cosmological defects in the inflationary epoch of the Universe. Experimental work is in progress to measure the properties of the interface itself, its equilibrium and dynamical behaviour. Dr Arrayas is experienced in studying and simulating the dynamics of interfaces and, in particular, has expertise in assessing the instability modes. Post-annihilation we think that the receding AB interface moves very quickly and some of the defect creation is likely due to instability in this motion.

**Scientific objectives of the project (12 lines max):**

The primary objective is to understand the dynamical properties of the A-B interface 2-brane. In the experiments a shaped magnetic field is used to control the boundary between the A and B phases.

In equilibrium the interface between the A and B phases sits in a free energy minimum that depends on the position of the critical transition field, the surface tension of the interface itself, and the difference in wetting energies between the two phases at the walls of the container. In previous work Dr Arrayas calculated equilibrium profiles of the interface in current and previous experiments, and also looked at the shape of a bubble of B phase completely surrounded by A phase. Now we will extend the analysis to the moving interface. Data from previous experiments remain unexplained, and new ideas can be tested in conjunction with ongoing experiments. Dr Arrayas will simulate the motion of the interface, in particular with a view to identifying possible instability modes that may lead to the formation of defects, and which we can look for in the experiments. He will also attempt to take into account the influence of the interface and its motion on the neighbouring textures in the A and B phases.

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

The experiment consists of a 6 cm long vertical cylinder of superfluid, 1.2 cm in diameter. A superconducting solenoid provides a controllable magnetic field gradient, allowing for the stabilisation of the AB interface across the cylinder at a temperature-dependent critical field around 340 mT. Ramping the current of the solenoid then ramps the field gradient and moves the AB interface up and down the cylinder, converting B phase to A phase and vice versa. The motion and properties of the interface are inferred from the behaviour of vibrating wire and quartz tuning fork resonators that project into the superfluid from the top, bottom, and sidewalls of the cylinder. These resonators are sensitive to the density of broken Cooper pair quasiparticle excitations, and are thus used to detect any changes as the interface is moved through the cylinder. Up to now Dr Arrayas has simulated the equilibrium interface profiles, and the quasi-equilibrium properties of an interface that is moved slowly through the cylinder past the detectors. During the previous visit we developed an experimental technique for much faster motion of the interface, using heating and cooling steps to adjust the position of the temperature-dependent critical field, rather than ramping the whole magnetic field profile. Dr. Arrayas will incorporate this into simulations. Furthermore, in the experiments we can hold the interface on one or more of the tuning fork resonators and oscillate the interface directly. Preliminary modelling work indicates that fast motion should lead to instabilities in the interface that

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| can grow. If these instability modes lead to the creation of defects in the surrounding A or B phases, then we will be able to detect them. There is also the possibility of directly exciting these instability modes using the tuning fork resonators. If we can show that such modes exist, then they almost certainly play a role in the creation of defects, when the two A-B branes collide, since this process has to be accompanied by very fast motion of the A-B interface. This is of crucial importance for understanding the mechanisms of brane annihilation. |

## 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** |
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| **If yes, please specify:** | |

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