Project Title: **Quantum geometry and topology in nonequilibrium quantum systems**

Funding availability: Competition-funded (worldwide)

Topologically protected systems have revolutionized our understanding of phases of matter in physics. They bring abstract mathematical concepts to real life in the form of experimentally observable quantized responses, which are extremely robust, hence, even constitute promising candidates for fault-tolerant quantum computation schemes. The study of topology out of equilibrium (e.g. under periodic driving with a laser light or quantum quenches) has further revealed new topological classifications and more exotic topological invariants. In recent years, we have discovered that topology and the geometry of quantum states are deeply intertwined, where the notions like quantum metric have been found to govern novel and seemingly distinct physical phenomena such as superconductivity, quantum metrology and fractional quantum Hall physics.

This theoretical PhD project will focus on investigating such topological and quantum geometric phenomena emerging in and out of equilibrium, by using analytical calculations supported by some numerics. It will also take advantage of state-of-the-art advances in ultracold atomic experiments which offer a high degree of control to observe these physics in quantum simulation settings.

The PhD candidate should have (or about to complete) an undergraduate or masters degree in Physics or a closely related subject (preferably first class degree or equivalent). Ideally, they will have a general theoretical physics background and an interest in areas such as condensed matter, topological phases, quantum simulations or ultracold quantum gases.

The project will take place in the group of Dr Nur Ünal (https://scholar.google.com/citations?hl=en&user=VIzeUlUAAAAJ) in the theoretical physics group at the School of Physics and Astronomy, University of Birmingham. The PhD candidate will be integrated into the Royal Society project of Dr Ünal on New frontiers in quantum geometry, topology and out-of-equilibrium dynamics. We have strong collaborations with several theory and experimental groups in the UK and internationally, such as in Cambridge, Manchester, Germany, France, the US, Japan etc. There will be opportunities, and in fact strong encouragement, to interact closely with these collaborations.

All highly motivated students are encouraged to contact Dr Nur Ünal at f.unal@bham.ac.uk for any informal inquiries about the project. You can apply at https://sits.bham.ac.uk/lpages/EPS005.htm and make sure you list the name of the supervisor Dr Ünal.

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The School of Physics and Astronomy is an Institute of Physics Juno Champion since 2014 and holder of the Athena SWAN Silver Award. Both initiatives recognise the School's commitment to promote diversity and equality, and to encourage better practice for all members of the community, whilst also working towards developing an equitable working culture in which all students and staff can achieve their full potential. We welcome applications from all qualified

applicants and encourage applications from traditionally under-represented groups in physics and astronomy including, but not limited to, women and Black, Asian and Minority Ethnic.

Funding notes:
Funding is awarded on competitive basis, and it will cover tuition fees and living stipend for 3.5 years. For details of the funding or any other inquiries contact f.unal@bham.ac.uk

References:

Breach et al., Editors' Suggestion Phys. Rev. Lett. 133, 093404 (2024)

Slager et al Nature Communications 15, 1144 (2024)

Kemp et al Phys. Rev. Research 4, 023120 (2022)

Project Title: **Topology and quantum dynamics in aperiodic crystals**

Funding availability: Competition-funded (worldwide)

Quasicrystals are rule breaking solids with a pattern that never repeats itself but still long-range ordered, of which Penrose lattice is a paradigmatic example. Falling in between perfectly periodic and fully disordered systems, they can host intriguing phenomena that cannot be found in regular solids e.g. anomalous conduction properties, multifractal spectrum and self-similar wavefunctions. While topological phases have been attracting tremendous attention in recent years in their own right, quasicrystals have been found to offer unique topological responses with no crystalline counterparts. This theoretical PhD project will focus on investigating such topological and dynamical phenomena arising in quasicrystals, uncovering the interplay of unconventional geometries in real space and quantum geometry in Hilbert space. It will involve analytical calculations supported by some numerics. Since quasicrystals are found in nature only under extreme conditions such as in meteorites, artificially created aperiodic lattices in quantum simulators (ultracold atoms, photonic lattices etc) offer unique opportunities to unveil mysteries of these exotic geometries. In particular, this project is part of an active collaboration with the experimental group in the University of Cambridge where an eight-fold symmetric quasicrystal has been recently realised in optical lattices, and the results will be directly communicated between theory and experiments.

The PhD candidate should have (or about to complete) an undergraduate or masters degree in Physics or a closely related subject (preferably first class degree or equivalent). Ideally, they will have a general theoretical physics background and an interest in areas such as condensed matter, topological phases, quantum simulations or ultracold quantum gases.

The project will take place in the group of Dr Nur Ünal (https://scholar.google.com/citations?hl=en&user=VIzeUlUAAAAJ) in the theoretical physics group at the School of Physics and Astronomy, University of Birmingham. The PhD candidate will be integrated into the Royal Society project of Dr Ünal on New frontiers in quantum

geometry, topology and out-of-equilibrium dynamics. We have strong collaborations with several theory and experimental groups in the UK and internationally, such as in Cambridge, Manchester, Germany, France, the US, Japan etc. There will be opportunities, and in fact strong encouragement, to interact closely with these collaborations.

All highly motivated students are encouraged to contact Dr Nur Ünal at f.unal@bham.ac.uk for any informal inquiries about the project. You can apply at https://sits.bham.ac.uk/lpages/EPS005.htm and make sure you list the name of the supervisor Dr Ünal.

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