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PREFACE

Quantum Phases: 50 years of the Aharonov–Bohm effect and 25 years of the Berry phase

This special issue celebrates the discovery of two of the most important aspects of quantum mechanics: the Aharonov–Bohm effect and the Berry phase. The issue includes work presented at two conferences, 50 Years of the Aharonov–Bohm Effect, 11–14 October 2009, Tel Aviv University, Israel, and the Aharonov–Bohm Effect and Berry Phase 50/25 Anniversary, 14–15 December 2009, Bristol University, UK.

The Aharonov–Bohm (AB) effect and the Berry phase have many things in common, apart from the happy coincidence that they were discovered 25 years apart, making possible such a joint anniversary. First, they were both discovered in the same place, the H H Wills Physics Laboratory, University of Bristol, UK.

Second, they both were there for everybody to see from day one, from the very beginning of quantum mechanics. They were, so to say, right on the surface; there was no need for sophisticated mathematics or involved constructions. Yet it took so long for somebody to see them. The explanation, we dare to speculate, is that they are so unusual, they challenge so much our everyday experience and ingrained intuitions about physics that it was difficult to recognise them.

Third, both the AB effect and the Berry phase are quintessentially quantum; they both manifest themselves as topological/geometric quantum phases.

The AB effect revolutionized our understanding of the role of potentials in physics. For the first time, it was shown that a particle moving in a field-free region could be affected by a field in a disjoint region. In doing so, it shattered one of the strongest held principles of physics. In the case of the Berry phase, the importance lies in its absolute generality—the topological/geometric phase named after Berry is acquired by all physical systems when the external parameters they depend upon undergo an adiabatic cyclic change. Remarkably this phase depends only on the geometry of the cyclic path in the abstract parameter space, a fact which deepens our appreciation of the underlying geometry of quantum mechanics.

The AB effect and the Berry phase are ubiquitous in modern physics and have implications ranging from the most fundamental to the very applied. First and foremost, they give a deeper understanding of the nature of quantum mechanics itself. Furthermore, we find them in fields as varied as cosmology, particle physics, non-abelian gauge theories, condensed matter, chemical and molecular physics, and laser dynamics. Generalizations of the AB effect to non-abelian gauge theories, such as the Wilson and 't Hooft loops, are important tools for studying confinement and spontaneous symmetry breaking. They explain charge quantization, the quantum Hall effect and the Josephson junction and also play a crucial role in electron microscope holography. Without them an understanding of many effects in the new field of mesoscopic physics, where tiny electronic circuits exhibit quantum behaviour, would be impossible.

Like good wine, the AB effect and the Berry phase become finer and more appreciated with time. Even though they appear in textbooks and encyclopaedias, the number of researchers thinking and publishing papers on these two effects is increasing annually. The AB effect and the Berry phase keep being observed in new systems and with every day that passes novel applications are routinely found. This special issue is just a small snapshot of the state of the art 50 and 25 years, respectively, from their discoveries.

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