David James Thouless

Preeminent condensed-matter physicist David James Thouless, an emeritus professor of physics at the University of Washington (UW) and a 2016 Nobel laureate, passed away on 6 April 2019 in Cambridge, UK. His most notable contributions are the so-called Thouless energy for electron transport in disordered media; Kosterlitz–Thouless (KT) phase transitions in two-dimensional equilibrium; the TKNN topological invariant, which explains the perfect quantization in the integer quantum Hall effect; and the Thouless adiabatic charge pump. He himself identified topological phenomena as the common thread throughout his work.

David was born on 21 September 1934 in Bearsden, Scotland. After earning his physics undergraduate degree in 1956 from Cambridge University, he went to Cornell University; he received his PhD there in 1958. He did his thesis work, applying perturbation methods to nuclear-matter theory, under adviser Hans Bethe. He conducted research at the University of California, Berkeley, and at the University of Birmingham under mentor Rudolf Peierls before returning to Cambridge in 1961 as a lecturer and fellow of Churchill College.

That same year, only three years after getting his PhD, David published his monograph *The Quantum Mechanics of Many-Body Systems*. The impact was swift. In his UW office in Seattle after he and his wife, Margaret, moved back to Cambridge in 2016, I and several colleagues found translations in Russian from 1963 and in German and Japanese from 1964.

David accepted a professorship in mathematical physics at the University of Birmingham in 1965. It was there in 1973 that he and Michael Kosterlitz wrote the KT papers, with a core message that order–disorder phase transitions can be topological in nature and do not necessarily involve a change in a local order parameter.

Phase transitions display spontaneous broken ergodicity. At boiling, a gas and liquid coexist but do not fluctuate into each other and can be distinguished locally by a jump in the order parameter density. The classification of phase transitions by local order parameters dates back to Johannes van der Waals in 1873 and was canonized by Lev Landau in 1937. Superfluid helium-4 films escape that classification. The onset of disorder is expressed by a nonlocal string-type order parameter, which represents vortex–vortex interactions.

Topological phase transitions are not necessarily a fundamental departure from the Landau theory. Nonlocal topological order often turns local under duality-type phase transitions. The point is that KT fundamentally revolutionized our approach to all phase transitions. I routinely represent them all in terms of topological domain-wall-type deconfinement.

David liked to say that theory typically lags behind experimental discoveries. But that's not the case with KT transitions, also known as BKT transitions to credit Vadim Berezinskii's contribution. David Bishop and John Reppy confirmed the theory's predictions in superfluids only five years later, in 1978. During a 1999 symposium in Seattle on the occasion of his 65th birthday, David was presented with a framed copy of their original data. He hung it in his office next to his Wolf Prize certificate; the cherished gift now resides in the Nobel Prize Museum.

David and Margaret moved to Seattle in 1980, where both held UW faculty positions—Margaret, a virologist, taught in the School of Public Health. It was at UW that David, Mahito Kohmoto, Peter Nightingale, and I discovered in 1982 the TKNN topological invariant that explains the integer quantum Hall effect. The Hall conductance, we found, is an observable that can be expressed as a closed contour integral. That property explained why the Hall conductance can only yield a multiple of e^2/h and why it is topologically protected from adiabatic disturbances, disorder in particular. That work turned out to be an application of Chern invariants and later served as an example of a Berry phase.

This decade we are witnessing a technological revolution in experimental control at the atomic level that is leading to novel quantum materials with phases that are generalizations of the TKNN invariant, including topological insulators. The renewed interest in our work, and how it affects current research, coincides with David being awarded the Nobel Prize in Physics in 2016. It was almost too late because of his health, but at the Nobel ceremony in Stockholm, my family and I were able to witness him cognitively enjoying receiving the prize.


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In the preface to his 1998 monograph *Topological Quantum Numbers in Nonrelativistic Physics*, David reflected on a discussion he'd had with Hans Dehmelt, the other Nobel laureate in the UW physics department. Dehmelt wondered "how the quantum Hall effect could possibly be used to determine the fine-structure constant when so little was known about the details of the devices used." Dehmelt received his physics Nobel in 1989 for the development of the ion trap. Next to his office, he displayed a Barnett Newman–like painting of perfect blue with one single dot, which resembled a trap filled with a single ion. In my presentations, I often contrast that reductionist painting with Vincent van Gogh's *Starry Night*, filled with vortices and chaos, to illustrate how complex systems include observables that are topologically protected and perfect. David played a central role in that fundamental shift in the paradigm.

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