Nobel Prize in Physics Once Again Highlights Essential Role of Neutron Scattering Facilities

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2016 Nobel Prize in Physics. The unique properties of the European Spallation Source machine design and instrumentation will give a major boost to research in condensed matter physics, and in particular to the Nobel-cited research into exotic states of matter.

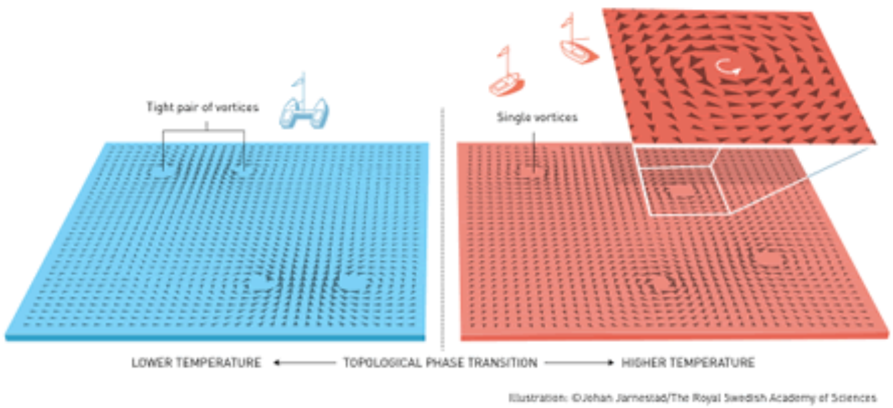
LUND and STOCKHOLM—A key moment in establishing the popular case for neutron science and the facilities that enable it came with the awarding of the Nobel Prize in Physics to Pierre-Gilles de Gennes in 1991. The importance of the Frenchman's theory of polymer reptation, developed in the 1970s, was only recognised following its experimental confirmation on neutron scattering instruments at the Institute Laue-Langevin (ILL). It was just three years later, in 1994, that the Nobel Committee for Physics at long last recognised Clifford Shull and Bertram Brockhouse for their work in the 1940s that established the fundamentals of neutron scattering as a way to, as the citation stated, 'answer the question of where atoms are and what atoms do".

2016 Nobel Laureates in Physics, from left, F. Duncan M. Haldane, David J. Thouless and J. Michael Kosterlitz are pictured here at Wednesday's Nobel Lecture in Stockholm. PHOTO: Screen capture from nobelprize.org live stream

Now, 25 years after de Gennes' prize, the Nobel Committee has once again indirectly highlighted the essential role of neutron scattering in establishing the laws of fundamental physics. The 2016 Nobel Prize in Physics will be awarded on Saturday to 'David J. Thouless, for one half, and F. Duncan M. Haldane with J. Michael Kosterlitz for the second half, for 'theoretical discoveries of topological phase transitions and topological phases of matter'."

Neutron Sources Key to Validation

The trio's work, puzzled over and published throughout the 1970s and early 1980s, has since served as the theoretical underpinning of the science of quantum topology. It is being recognised now largely due to validation provided by experiments performed at neutron sources over the last 25 years. That research has led to advances in the understanding of fields as diverse as superconductivity, lasers, superfluids and thin magnetic films.



Phase transition. This occurs when phases of matter transition between each other, such as when ice melts and becomes water. Using topology, Kosterlitz and Thouless described a topological phase transition in a thin layer of very cold matter. In the cold, vortex pairs form and then suddenly separate at the temperature of the phase transition. This was one of the twentieth century's most important discoveries in the physics of condensed matter. SOURCE: The Royal Swedish Academy of Sciences / ILL: ©Johan Jarnestad

'This is the interesting thing about this prize," says ESS Instrument Scientist Pascale Deen, whose experimental research in condensed matter physics touches on aspects of the theoretical work of the prize winners. 'Usually there would be a state of observation—you would have a material that doesn't quite behave in the way you expect it to and then you keep probing it with different techniques until a suitable explanation can link theory to experiment. Here, you have physics that is well described theoretically, and then you try to find materials that describe that physics. So that's what's so nice about this prize, the link between theory and experiment is really quite strong."

Haldane spent four critical years as a post-doc in ILL's theory group just prior to publishing his Nobel-winning work, and the key publications cited by the Committee include experiments by researchers in the 1990s, 2000s and 2010s at neutron sources like ILL, ISIS in the UK, and the Spallation Neutron Source in the US. Ongoing research with neutrons at these facilities and at other ESS partner labs such as the Paul Scherrer Institute in Switzerland and the FRMII reactor in Munich, continue to bring to light the scientific value of the theories and their far-reaching potential for practical applications.

New States of Matter Give Rise to Dreams of Fantastical Innovations

What Thouless, Haldane and Kosterlitz achieved was to apply the mathematical principles of topology to explain the physical properties of very thin atomic structures—matter so thin that it is described as 'two-dimensional" or in the case of Haldane's theoretical chain of single atoms, 'one-dimensional". A consequence of the mathematics was to predict that these flattened materials would experience unexpected phase transitions as the material's temperature was raised or lowered.

What Thouless and Kosterlitz were able to see with mathematics in the early 1970s, researchers were able to see with neutrons decades later, identifying these new states of matter. This research has spawned the science fiction-like possibilities associated with unrealised technologies such as room-temperature superconductors, quantum computing and the frictionless electronics of topological insulators. But, as Deen points out, more research and more advanced facilities are necessary to advance the field toward these far-out technologies.

'The generic answer [to the question of applications] is always, 'Oh yes!', you might have spin entanglement and therefore you might imagine immediately using it for spintronics applications, but we're really not there yet. We don't understand this phenomena in enough detail. What's really interesting for us is that it's a deviation from the fundamental laws that we were taught 10 years ago. So we're showing that quantum behaviour is very distinct from classical behaviour and we try to understand these behaviours."

RIGHT: ESS scientists Pascale Deen (top) and Arno Hiess. PHOTOS: ESS

European Spallation Source Represents 'Huge Leap' Forward

One of the major drivers behind the design and construction of ESS is to service the growing field of condensed matter physics. The key is ESS' ability to generate more neutron flux, allowing researchers to probe ever smaller samples, and thus a widening array of materials.

'The field is slow-moving because we don't have enough flux," says Head of the ESS Scientific Activities Division Arno Hiess, who also works in the field of quantum phenomena. 'ESS will be a huge leap, because of its unique source performance and state of the art instrumentation. We'll be able to access compounds that we haven't been able to probe and uncover emergent behaviours. Moreover, we'll be able to study time-dependent phenomena. Because neutrons are so uniquely brilliant at proving the dynamic state of magnetic order, we will really make a huge impact in this field."

However, insists Deen, the Nobel Prize in this case is really being awarded for the change it marks in our understanding of the fundamental physical laws of the universe.

'The prize was really given for the beauty of the mathematics in a sense. Like the search for the Higgs Boson, there's no technological goal behind the search, simply a fundamental interest. The question is always, because you do condensed matter you must be looking at something that's applied, but in this case it's not. In the same way that the study of electricity was fundamental physics in its day. Initially there was no clear view to how it could be used. Equivalently, in the study of novel states at the moment, we're just trying to understand these phenomena."

**Duncan Haldane will be reprising his Physics Nobel Lecture at the Niels Bohr Institute in Copenhagen next Wednesday, December 14. More information at the NBI website.*

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