The inadequacy of the **ρ**-T curve for phase transitions in the presence of magnetic fields

Shengnan Zhang[1], Zhong Fang[1,2,3], Hongming Weng[1,2,3], and **Quansheng Wu[1,2]***

[1]Beijing National Laboratory for Condensed Matter Physics and Institute of physics, Chinese academy of sciences, Beijing 100190, China

[2]University of Chinese academy of sciences, Beijing 100049, China and

[3]Songshan Lake Materials Laboratory, Dongguan, Guangdong 523808, China

The ρ(T) curve is traditionally employed to discern metallic, semiconductor, and insulating behaviors in materials, with any deviations often interpreted as indicative of phase transitions. However, does this interpretation hold under the influence of a magnetic field? Our research addresses this critical question by reevaluating the ρ(T) curve in the presence of magnetic field. We uncover that metal-insulator shifts and reentrant metallic states may not indicate true phase transitions but rather originate from the scaling behavior of magnetoresistance, influenced by magnetic field and temperature through a power-law dependence. Employing advanced first-principles calculations and the Boltzmann method, we analyzed the magnetoresistance of SiP_2 and NbP across a range of conditions, successfully explaining not only the reentrant behavior observed in experiments but also resolving the discrepancies in magnetoresistance behavior reported by different research groups. These findings challenge the conventional use of the ρ(T) curve as a straightforward indicator of phase transitions under magnetic conditions, highlighting the essential need to exclude typical magnetoresistance effects due to the Lorentz force before confirming such transitions. This novel insight reshapes our understanding of complex material properties in magnetic fields and sets a new precedent for the interpretation of transport phenomena in condensed matter physics.

Biography:

Quansheng Wu is a Distinguished Research Fellow and Ph.D. Supervisor at the Institute of Physics, Chinese Academy of Sciences (CAS). He received his Ph.D. from the Institute of Physics, CAS in 2013. From 2015 to 2021, he conducted postdoctoral research at the Swiss Federal Institute of Technology Zurich (ETH Zurich) and the Swiss Federal Institute of Technology Lausanne (EPFL). At the end of 2021, he joined the Institute of Physics, CAS. His main research areas are topological materials and their transport properties, as well as the application of machine learning in condensed matter physics. He has published more than 50 articles in prominent journals such as Science, Nature, and Physical Review Letters (PRL), with over 8,800 citations in SCI and an H-index of 31. The WannierTools software he developed has become an essential tool in the field of topological materials, with over 1,900 citations.