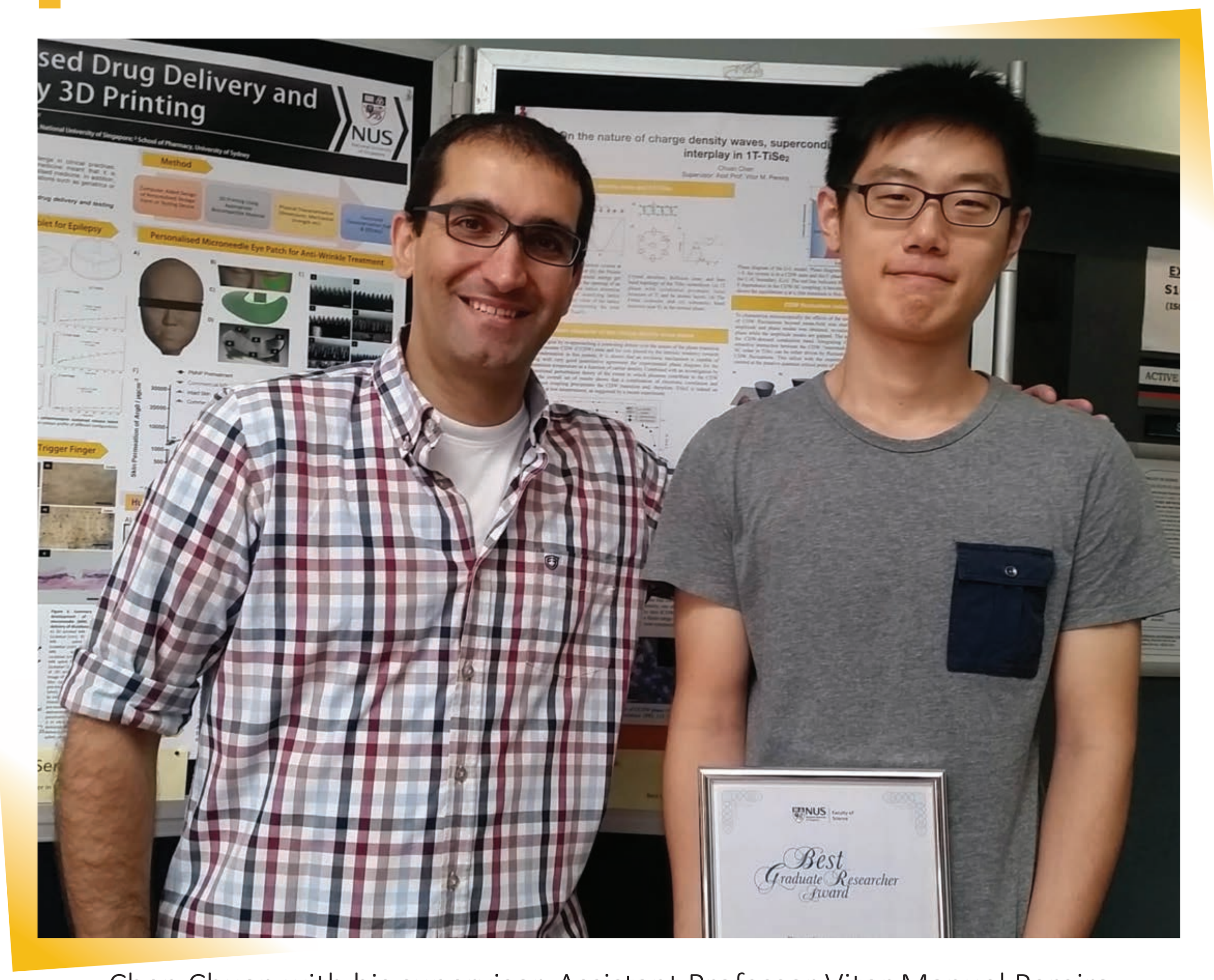
Chen Chuan



Chen Chuan with his supervisor, Assistant Professor Vitor Manuel Pereira

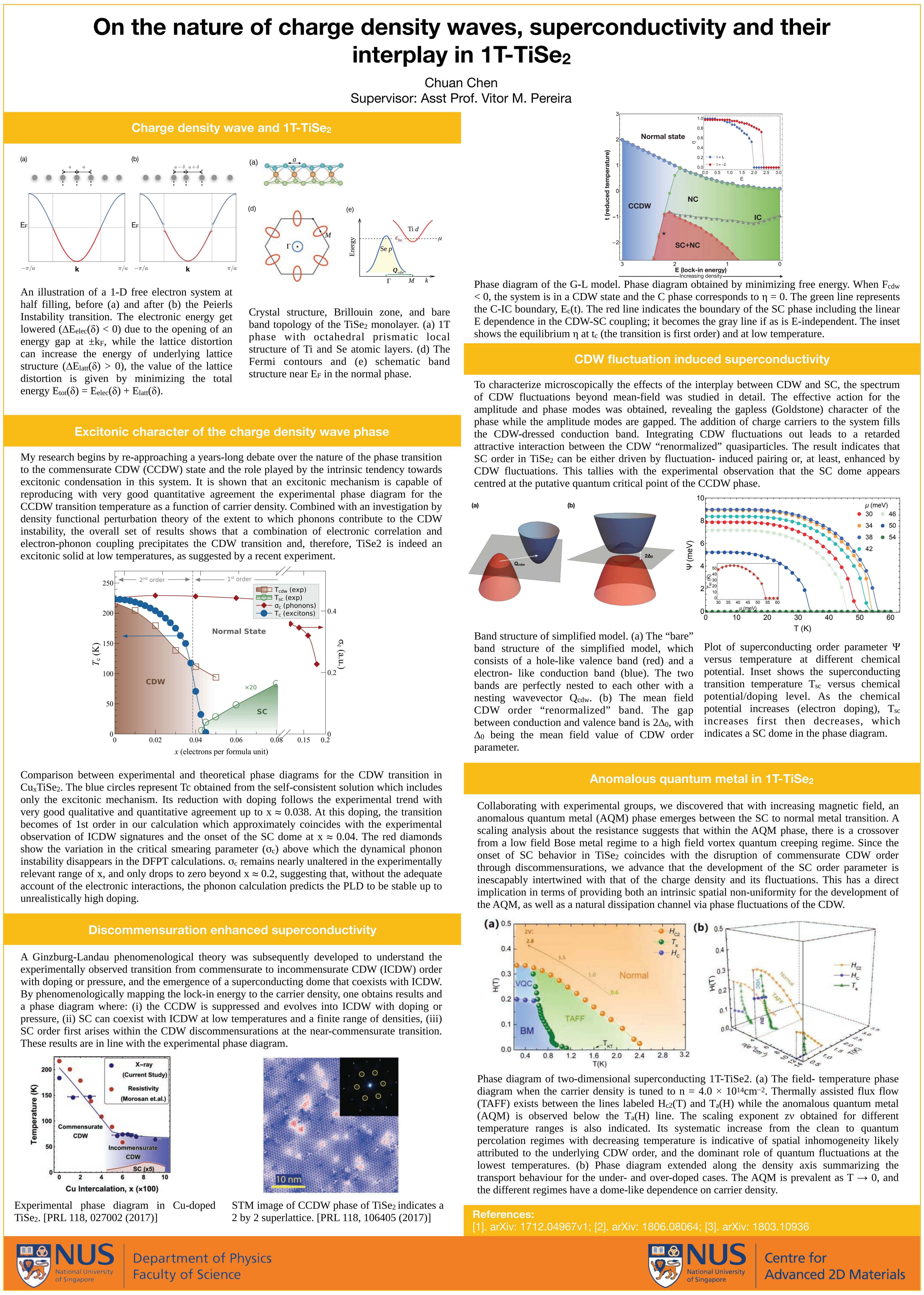
Achievements

Throughout his PhD in Physics, Chuan developed an original body of theoretical work that provides the most comprehensive and detailed investigation to date of the charge-density wave (CDW) instability in TiSe2, its microscopic underpinnings as an excitonic condensation instability, and how CDW fluctuations might be essential to explain the experimental observation of superconductivity in this compound at low temperatures.

His work is reported in a series of 4 research papers, the first of which (published in Physical Review Letters) establishes the crucial role of the excitonic instability, possibly settling a question that has endured 40 years of polarizing discussions in the literature and the community.

The momentum gained in this first paper has been fruitfully directed to building a comprehensive theoretical picture of not only CDW physics, but also how the CDW order might be responsible for the emergence of superconductivity with doping in TiSe2. Unlike the CDW problem that has a long history, the nature of the superconductivity in this system is a new and entirely unexplored topic. Chuan's subsequent work contributes the first theory that reproduces the whole phase diagram. In his second paper nearly ready for submission, he establishes how the two order parameters must be coupled at the level of a Ginzburg-Landau theory in order to explain the experiments; he furthermore predicts that superconductivity is likely to be spatially inhomogeneous and strongly associated with CDW discommensurations, which agrees with recent experimental suggestions. His third paper is the necessary follow-up that goes back to the microscopic Hamiltonian and demonstrates that fluctuations of CDW order can induce superconducting pairing. The implication is that thermal and quantum fluctuations of the excitonic state he established with his first paper are the likely microscopic origin of the superconducting dome observed experimentally. Fluctuation-induced pairing has deep connections with models that explain the high-temperature superconductivity in cuprate oxides.

Finally, in collaboration with an experimental group at NUS, Chuan contributed theory to interpret and understand the superconducting phase diagram of strictly two-dimensional TiSe2, in which magneto-transport measurements reveal a quantum phase transition from superconducting to a Bose-metallic phase. The latter has been observed recently in a number of two-dimensional superconductors and is a new challenge in our understanding of the superconducting ground state in two-dimensions.



Research Areas

The core of Chuan's research is dedicated to the theoretical understanding of effects arising from electronic interactions and the interplay between different microscopic degrees of freedom (including disorder) in so-called strongly-correlated systems. He has focused, in particular, in the microscopic interplay between charge density waves (CDW) and superconductivity (SC) in either layered 3D or strictly 2D crystals.

Generically, the interplay of CDW and SC orders is one of the perennial topics of interest in condensed matter physics because there are specific reasons to believe that progress in characterizing the underlying physics can unlock many of the unresolved problems in high-temperature superconductivity, where competition among spin or charge order and SC are also present. Transitions among these phases are usually driven by temperature or electronic doping. Research on these correlated ground states has been explosively revived over the last 5 years with the possibility of exploring them in a number of different 2D realizations of layered crystals, because of the ability of tuning the carrier density on demand by field effect, without introducing disorder. This is currently one of the hottest topics in experimental and theoretical condensed matter research, as documented by the pace of high-profile publications appearing in Science and Nature-branded journals during 2016-2018.

Publications

[1] C. Chen, B. Singh, H. Lin, Vitor M. Pereira, "Reproduction of the Charge Density Wave Phase Diagram in 1T-TiSe2 Exposes its Excitonic Character". Phys. Rev. Lett. 121, 226602 (2018).

[2] C. Chen, L. Su, A. H. Castro Neto, Vitor M. Pereira, "Discommensuration-enhanced superconductivity in the charge density wave phases of transition-metal dichalcogenides". Submitted. arXiv:1806.08064 (2018).

[3] C. Chen, A. H. Castro Neto, Vitor M. Pereira, "Pairing induced by fluctuations of an excitonic insulator: the case of superconductivity in TiSe2". In preparation.

[4] L. Li, C. Chen, et al., "Anomalous quantum metal in a 2D crystalline superconductor with intrinsic electronic non-uniformity". Submitted. arXiv:1803.10936 (2018).

Chen Chuan receiving his award from Prof Lu Yixin, Vice Dean (Graduate Studies and Safety)

Awards

- ✓ 2018- Best Graduate Researcher Award (Physics). Faculty of Science, NUS.
- ✓ 2013- 1st Class Scholarship of National Scientific Base for Talented Persons 2013-2014. Sichuan University.
- ✓ 2012- 1st Class Scholarship of National Scientific Base for Talented Persons 2012-2013. Sichuan University.
- ✓ 2011- National Scholarship 2011-2012. Sichuan University.
- ✓ 2010- National Scholarship 2010-2011. Sichuan University.