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Sofja Kovalevskaja Award brings superconducting spintronics expertise to Konstanz

Sofja Kovalevskaja Award winner Dr Angelo Di Bernardo from the University of Cambridge to establish a new research hub in the field of superconducting spintronics at the University of Konstanz's Department of Physics

Starting on 1 October 2019, the Sofja Kovalevskaja Award winner Dr Angelo Di Bernardo will contribute to the research carried out at the University of Konstanz in the area of Nano and Materials Science with his expertise in superconducting spintronics. Di Bernardo, who is currently a Junior Research Fellow (St. John's College) in the Department of Materials Science and Metallurgy at the University of Cambridge, is one of only six early career researchers worldwide to be honoured with one of this year's Sofja Kovalevskaja Awards, which are conferred by the Alexander von Humboldt Foundation.

With funding of up to 1.65 million euros, the Sofja Kovalevskaja Award is Germany's most highly-endowed research award for early career researchers. It is funded by the Federal Ministry of Education and Research and seeks to bring international scholars and scientists already recognised as outstanding talents to Germany to pursue creative and new research avenues in their fields of study. Successful applicants must have completed their doctorate no more than six years before applying and may use the award to spend up to five years at a German university of their choice to carry out a research project.

For his project entitled "Superconducting Spintronics with Oxides and 2D Materials", Angelo Di Bernardo has been granted the maximum funding amount of 1.65 million euros, which he intends to use to establish a nationally leading research hub in the field of superconducting spintronics at the University of Konstanz. For this purpose, he will work closely with Professors Elke Scheer and Wolfgang Belzig from the Department of Physics, who currently lead the Mesoscopic Systems and the Quantum Transport groups, respectively.

Superconducting spintronics

Angelo Di Bernardo investigates unconventional superconducting states emerging at the interface between superconductors and other magnetic or non-magnetic materials. Superconductors are special metals that can propagate current without energy dissipation when cooled down below their so-called critical temperatures. Superconducting computers, for instance, could thus be used to drastically reduce the energy required to power large data centres, which are already responsible for three percent of the world's electricity consumption.

"My research concerns the investigation and characterisation of physical phenomena deriving from the interaction between superconductor and ferromagnet materials", explains Di Bernardo. "This is done to develop a new form of spin-electronics (spintronics) with low energy dissipation". In spintronics, information is processed via the spin carried by electrons: "The spin of an electron can be thought of as a little magnet with the 'north pole' pointing either 'up' or 'down'. These two distinguishable spin states can be used to encode the bits 1 and 0 in spintronic devices, which has already had a profound impact on the development of modern memory units in computers and phones".

One major problem of spintronic devices is the large input currents that such devices require to operate. This problem can be overcome by combining superconductor and ferromagnet materials, says Di Bernardo: "Although logic processing based on electrons' spins is faster than the charge-based equivalent used in semiconductor transistors, the input currents required by spintronics devices are much larger compared to those needed by equivalent semiconductor devices. Superconductors can solve this problem because they have no energy dissipation. However, coupling a superconductor to a ferromagnet is not easy, mainly because electrons in superconductors form pairs with opposite spin alignment (spin-singlet pairs). These pairs are carrying the dissipationless current. Spin-singlet pairs are easily broken after entering a ferromagnet, which favours one spin orientation over the other due to its physical properties. In recent years, however, we have demonstrated that, by coupling a superconducting material to a ferromagnet, spin-singlet pairs can be converted into spin-aligned (spin-triplet) electron pairs which are fully polarized and can propagate in a ferromagnet over large distances. This means that they can be exploited in energy-efficient spintronics devices". The ultimate goal is to fabricate devices that do not waste any energy and can thus be used to build the next generation of quantum computing technologies as well as large-scale computing facilities.

Oxides and 2D materials: Towards a new age of supercomputing
In Konstanz, Di Bernardo will focus on fabricating and processing the materials needed for superconducting spintronic devices. As Professor Elke Scheer explains: "Dr Di Bernardo's main expertise is in using unconventional materials for superconductor-ferromagnet structures such as high-quality multilayers using a variety of physical vapour deposition and nanofabrication techniques. These include pulsed laser deposition, magnetron sputtering and mechanical exfoliation. While in our group we are able to grow simple metals, we do not currently have the know-how to fabricate oxides and 2D heterostructures with much more sophisticated and new functionalities. Dr Di Bernardo's work in this field will close this gap". According to Professor Wolfgang Belzig, who specialises in theoretical condensed matter physics, the precise design of these structures is absolutely crucial for achieving functional operation: "Close interaction with theoretical and numerical model predictions is essential to fabricate such devices and understand their physical properties".

Building on the internationally leading expertise as well as state-of-the-art spectroscopy and low-temperature measurement facilities provided by Elke Scheer and her team, Di Bernardo plans to use part of his Sofja Kovalevskaja Award to install a new pulsed laser deposition (PLD) facility at the University of Konstanz to fabricate oxide thin film multilayers. The multilayers will then be patterned in functional nanodevices for testing. "Exploiting the complex range of physical properties of oxides and 2D materials, we will be able to build devices with a much wider range of functionalities. In the near future, we may also learn how to operate such devices electrically, which has never been achieved before", says Di Bernardo.

To date, spintronics devices are operated and controlled magnetically, which puts a limitation on how small they can be – due, for instance, to the minimum size of the magnetic element required to control a single device without interfering with others. "Controlling spintronic devices electrically would be a giant leap because it can be done locally by using a contact and applying a voltage that switches the device from 0 to 1 and from 1 to 0", explains Di Bernardo. "If we are successful in creating spintronics devices that are small enough and energy-efficient enough, we could be moving into a completely new era of supercomputing".

About Angelo Di Bernardo
Angelo Di Bernardo holds a Master of Engineering (Bioengineering) from the University of Naples Federico II, a Master of Science (Nanoscience) from Arizona State University and a master's degree and PhD in Nanoscience from the University of Cambridge.

Over his academic career, he has been awarded several highly competitive scholarships, including a Fulbright Self-Placed Scholarship for Italian Students (2011/2012) to pursue his master's degree in Arizona and a Schiff Foundation Scholarship (2012) for graduate students from the University of Cambridge. In 2016/2017, he was selected as one of five Junior Research Fellows by St. John's

College, University of Cambridge. Di Bernardo also received several prizes for his work in the field of superconducting spintronics, including the international IEEE Council on Superconductivity Graduate Study Fellowship (2015), the European Society for Applied Superconductivity Award (2017) and the Brian Pippard Prize (2018) of the Institute of Physics.

Facts:

- Superconducting spintronics expert and 2019 Sofja Kovalevskaja Award winner Dr Angelo Di Bernardo from the University of Cambridge to join the University of Konstanz's Department of Physics on 1 October 2019
- Boost for research priority Nano and Materials Science in the area of superconducting spintronics, in particular with regard to device and materials fabrication for superconductor-ferromagnet heterostructures
- Sofja Kovalevskaja Award is Germany's most highly endowed research award for early career researchers worth up to 1.65 million euros, conferred by the Alexander von Humboldt Foundation
- Funding amount for Dr Di Bernardo's research project at the University of Konstanz: 1.65 million euros
- Funding period: five years

Note to editors:
An image is available for download here: https://cms.uni-konstanz.de/fileadmin/pi/fileserver/2019/Bilder/sofja_kovalevskaja_award_angelo_di_Bernardo.jpg
Caption: Dr Angelo Di Bernardo, recipient of one of six 2019 Sofja Kovalevskaja Awards
Image: Angelo Di Bernardo

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