# Novel Effects in Single Atom Transistors

**Dr Giuseppe C. Tettamanzi**
Section Photronic Devices (PD), Kavli Institute of Nanoscience
Delft University of Technology, Netherlands

Since the origin of semiconductor industry, dopants have been playing a passive role in CMOS devices. But, as the miniaturization approaches the atomic size limit, the position and the presence of a *single dopant* can now dramatically change the electrical characteristic of the devices [1,2]. This is, from one side, a great problem for the semiconductor industry, but, from another side, it gives the opportunity to address the single dopant in ultra-scaled silicon transistors [1,2]. As an example of this, we are now able to experimentally study a novel system, a single shallow donor in a three-terminal geometry and observe the complicated transport mechanisms like the orbital Kondo effects [3] and the Fano-Kondo effects [4] in silicon nanostructures. These are of fundamental interest since they explore the role of the valley (orbital) degree of freedom and of the coherent transport in this material system. It has been theoretically predicted that the valley degeneracy leads to SU(4)-correlations, which entangles the spin, and momentum of exchanged electrons. In the Coulomb-blockade regime with a single electron on the system we observe a set of transport resonances. We show these resonances to originate from SU(4) Kondo effects by means of their dependence on temperature, magnetic field, orbital splitting and their substructure. The entanglement between spin and momentum provides new opportunities for spin control in silicon. For example, we show that some devices operate as a gated spin filter in silicon with a potentially high transitivity [3]. We also show that by means of our system we can study quantum phase transitions [5]. Last, by using the Kondo transport channel, we demonstrate the first ever observation of the coherent exchange of electrons between two donors in a two donors system in silicon, resulting in a Fano resonance [4]. If time will allows, I will also discuss also some recent results on Nano-Scale Superconducting Electronics [6].

**References**

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**Contacts**

Speaker: G.C.Tettamanzi@tudelft.nl
Organizer: olivero@to.infn.it