A Quantum Simulator to Emulate Molecular Structure

Brian Kiraly
School of Physics and Astronomy, University of Nottingham

With increasingly sophisticated experimental systems, such as optically trapped cold atoms, lithographically defined quantum dots, or artificially assembled molecules on surfaces, our ability to quantitatively simulate solid state systems has led to remarkable advances in our understanding of the ways in which structure, dimensionality, and various types of interactions produce complex quantum states of matter. In this talk, I will detail the experimental development of a new quantum simulator based on an electrostatically sculpted two-dimensional electron gas on the surface of the semiconductor indium antimonide. The experimental work was conducted in the Scanning Probe Microscopy Department at Radboud University, led by Prof. Alex Khajetoorians, in collaboration with the Theory of Condensed Matter and Theoretical Chemistry Departments at Radboud. Manipulating individual cesium atoms on the semiconductor's surface with atomic precision, we are able to create artificial atoms hosting zero-dimensional bound states resembling atomic orbitals. As these states reside within the bulk band gap of the indium antimonide, they are weakly coupled to the substrate. We then show that the artificial atoms exhibit long-range coupling, leading to the formation of clearly distinguished bonding-antibonding orbitals. Finally, creating artificial "molecules" (fig. 1) from these individual "atoms," we show that the atomic states exhibit multi-orbital character and hybridise in a fashion nearly identical to molecules in nature.

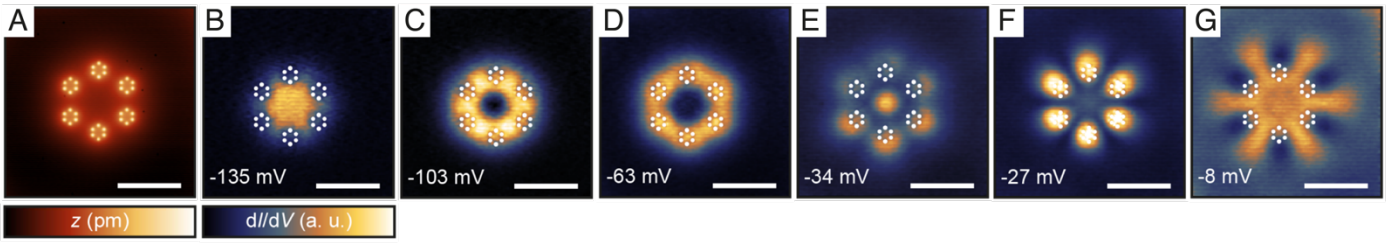

Figure 1 – Artificial Benzene. (a) Scanning tunnelling microscopy constant current image of Cs atoms on InSb arranged into six artificial atoms to form an artificial benzene molecule. (b-g) Scanning tunnelling spectroscopy maps of various "molecular orbitals" of the artificial benzene mapped at the energies at the lower left hand corners. All scale bars are 20 nm.