Artificial atomic scale materials: Discovering how electrons fatten

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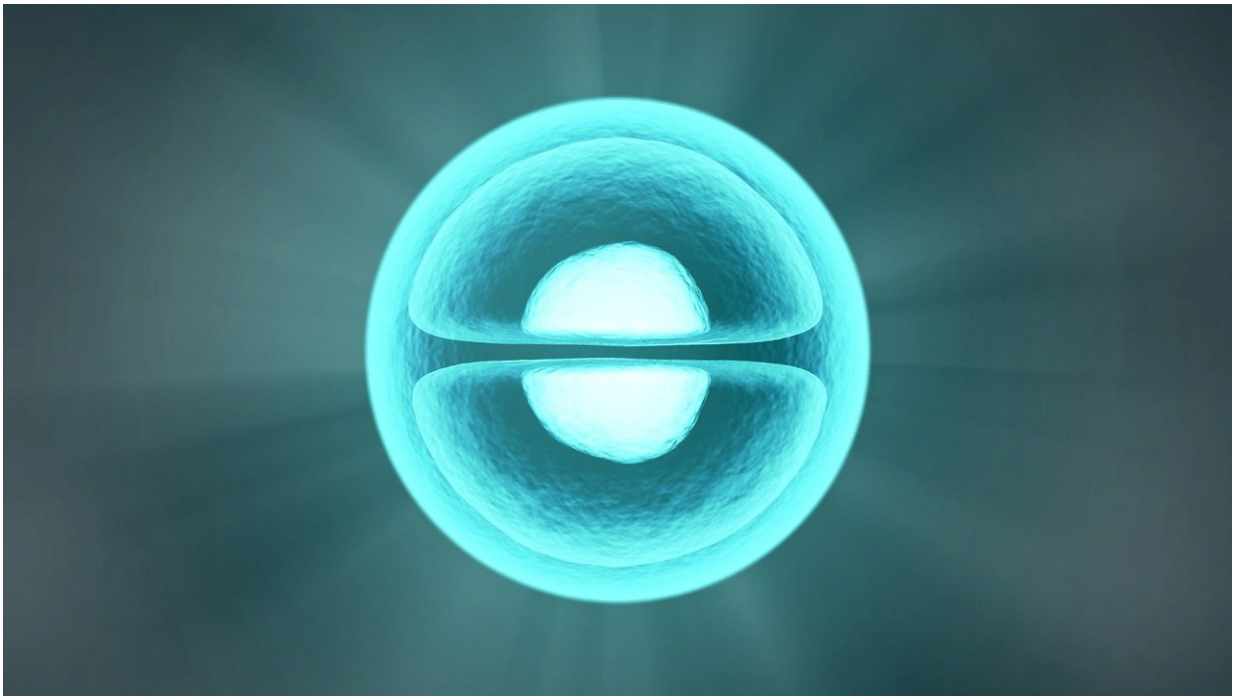

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A single and isolated electron has a clear electrical charge, magnetic moment and mass, and its free movement can be precisely predicted. Spanish scientists fabricated a nanoscale artificial material manipulating atoms one after the other and discovered that electrons can become heavier. Heavy electrons are promising particles which endow new functionalities to novel materials. This study is the result of an

international collaboration lead by the Instituto de Nanociencia de Aragón and the Instituto de Ciencia de Materiales de Aragón (ICMA), in which scientists at CIC nanoGUNE participated, together with members of the Centro de Física de Materiales (CFM) in San Sebastian, and the Charles University and Czech Academy of Sciences, in the Czech Republic.

The study has been publish in the journal *Nature Communications* and shows that it is possible to fabricate artificial materials, one by one, to produce electronic and magnetic properties that do not exist in any material found in nature. In this case, the scientists observed that conventional electrons in a metal become heavy electrons (the technical term is heavy fermions) in the proximity of ordered atomic structures of magnetic atoms (cobalt) arranged over the surface. Heavy fermions are electronic states that appear when normal electrons, which are intrinsically magnetic, are attracted towards the structure of magnetic atoms periodically arranged.

The researchers employed a scanning tunnelling microscope at low temperatures to study the shape of these electronic states and demonstrate that they correspond to the emergence of a heavy fermion state. This is the first time that the formation of such novel states of matter was monitored by constructing the artificial material one atom at a time. "We found that the magnetic fingerprint of this electrons extended delocalized along a magnetic chain of up to 20 cobalt atoms, allowing us to demonstrate that they correspond to a new electronic state of matter, and provide a theoretical model for creation of heavy electrons that could be extended to other systems, thus boosting the search of artificial materials with novel functional properties." Explains David Serrate, scientist at ICMA and leader of this study.

The exotic electronic and magnetic properties of these materials anticipate their possible use for applications such as sensors,

superconducting devices, or to explore critical quantum processes. Heavy electrons behave drastically different than normal electrons because their response to temperature and pressure of magnetic fields scales with the mass of the electrons. Additionally, the observation of these novel states inspire new theoretical models that allows us to explore the quantum limits of matter and design new artificial materials with customized electronic behaviour.

More information: María Moro-Lagares et al, Real space manifestations of coherent screening in atomic scale Kondo lattices, *Nature Communications* (2019). DOI: 10.1038/s41467-019-10103-5

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