Experimental Solution of the Thomson Problem

Thomas Pohl[1], Jan Mayerhofer[1], Shengfu Yang[2], Andrew M. Ellis[2], Paul Scheier[1]

[1]Institut für Ionenphysik und Angewandte Physik, University of Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria
[2]School of Chemistry, University of Leicester, University Road, Leicester, LE1 7RH, UK
paul.scheier@uibk.ac.at

In multiply charged helium droplets like-charge Coulomb repulsion pushes the charge centers to the surface of the superfluid droplet where they adopt a minimum energy configuration in the form of the famous Thomson problem[1]. Coherent diffraction imaging of large multiply charged helium droplets doped with xenon confirms that most for the dopants are found in the form of clusters close to the surface of the droplet[2], however, the quality of the images does not allow a comparison with the solution of the Thomson problem for any specific number of charges.
By doping multiply charged helium droplets with gold vapor, monodisperse nanoparticles containing typically a few thousand atoms are formed. Upon soft-landing onto a transmission electron microscope (TEM) grid, each droplet prints its gold particles onto the substrate. The orthographic projection of the numerical solution of the Thomson problem[3] can be fitted to the experimental TEM images of individual droplets by appropriate rotation and scaling. For droplets with a final radius smaller than 200 nm we obtain perfect agreement between the experimental results and the numerical solution of the Thomson problem. This indicates minimal displacement of the several 100 kDa gold particles upon surface collision of the doped helium droplets. The regular patterns observed in imprints of helium droplets with a radius larger than 400 nm can only be explained when particles located on the back hemisphere are splashed sideways and backwards[4].

References:

[1] Thomson, J. J. On the structure of the atom. Philosophical Magazine, 1904, 7, 237–265. https://doi.org/10.1080/14786440409463107
[2] Feinberg, A. J.; et al. X-ray diffractive imaging of highly ionized helium nanodroplets. Physical Review Research, 2022, 4, L022063. https://doi.org/10.1103/PhysRevResearch.4.L022063
[3] Wales, D. J.; Ulker, S. Structure and Dynamics of Spherical Crystals Characterised for the Thomson Problem. Physical Review B, 2006, 74, 212101. https://doi.org/10.1103/PhysRevB.74.212101
[4] Martini, P.; et al. Splashing of Large Helium Nanodroplets upon Surface Collisions. Physical Review Letters, 2021, 127, 263401. https://doi.org/10.1103/PhysRevLett.127.263401