Barcelona, April 26, 2017

# Enigmatic Molecules of Helium and Molecules in Enigmatic Helium

J. Peter Toennies

Max Plank-Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen, Germany, jtoenni@gwdg.de

Helium is an element of many superlatives. The bosonic nature, small mass and weak intermolecular forces explain why it is the only substance that remains liquid down to zero Kelvin and the only naturally occurring superfluid.

Small clusters of helium in highly expanded atomic beams also exhibit the most extraordinary behavior of all naturally occurring elements.[1] In an extraordinary experiment in 2015, the He trimer was found to have a huge Efimov state with more than 100 Å size, making it one of the largest of all molecules, comparable to a DNA molecule [2]. This is the first observation of the size of this counter-intuitive quantum species predicted by Efimov in 1970.

Droplets with $10^3$ – $10^4$ are also readily produced in cryogenic free jet expansions and are studied via the spectroscopy of embedded closed-shell molecules. In the infra-red small molecules (e.g. OCS, $SF_6$) have very sharp rotational lines indicating that the molecules rotate freely inside the droplets. These experiments have established that finite-sized $^4$He droplets are superfluid making them the coldest and gentlest of all matrices for spectroscopic studies [3].

At the end of my lecture present day experiments directed at extending the spectroscopies to large organic and biomolecules[4] and recent X-ray diffraction experiments carried out at SLAC on *individual* pure and doped droplets [5] will be described. They point the way towards many new exciting areas of research in physics, chemical physics and chemistry.

[1] J. P. Toennies, Mol. Phys. 111, 1879 (2013). [2] M. Kunitzki *et al*., Science 348, 551 (2015). [3] J. P. Toennies and A. F. Vilesov, Angew. Chem. Int. Edit. 43, 2622 (2004). [4] A.I.Gonzales Florez et al. Angew. Chem. Int. Ed. 55,3295 (2016). [5] L. F. Gomez et al. Science 345,906 (2014).