Research Snippet #1 (Jan 14) - Super-excited aluminium atoms floating on liquid helium

Superfluid helium is one of the strangest known materials. Existing only at temperatures near to absolute zero (-273°C), it has properties that are dominated by the counterintuitive world of quantum mechanics. At Leicester we explore the properties of nanoscale-sized droplets of superfluid liquid helium and one aim is to grow metal nanoparticles inside these droplets. In a recent experiment an attempt was made to inject aluminium atoms into the droplets by a violent process known as laser ablation. To our surprise the aluminium atoms separate into two groups: electronically cold atoms that go inside the helium droplet and a second group of highly excited atoms that float on the surface of the droplet. These two types of Al atoms were distinguished using laser spectroscopy. The separation of cold and excited metal atoms is a potentially new way of transporting and exploring exotic states of matter, such as Rydberg atoms.

This work is a joint investigation between the universities of Leicester and Nottingham and includes contributions from Prof. Andrew M.
Ellis, Dr Shengfu Yang, Dr Gautam Sarma, Dr Adrian Boatwright, Ethan Cunningham (all Leicester), Prof. Tony Stace, Jay Jeffs, Louise Rimmer and Nick Besley (all Nottingham). Leicester, Prof. Tony Stace, Jay Jeffs, Louise Rimmer and Nick Besley (all Nottingham).

Ultraviolet spectra of aluminium atoms floating on a superfluid helium nanodroplets.

An aluminium atom sat on the surface of a small cluster of helium atoms.

Research Snippet #2 (Jan 14) - Giant magnetic moments in metal nanoparticles

Performing chemistry in a liquid inside a vacuum chamber and at a temperature near absolute zero (below -272 °C) would at first seem like an odd approach to controlling the magnetic properties of materials. The liquid in this case is superfluid helium, a quantum fluid with remarkable properties including zero resistance to flow and the ability to conduct heat away at a rate of ten billion degrees per second. Most remarkably this material has been used as a method to capture atoms one by one, where they stick together inside, in order to carry out simple chemistry. The key to this process is the creation of nanodroplets of this unique liquid which are ten thousand times smaller than the diameter of a human hair. These ultra-cold nanoreactors can be used to grow nanoparticles and a team at Leicester led by Dr Shengfu Yang, Professor Andrew M. Ellis and Professor Chris Binns are using these to grow unique particles with exceptional magnetic properties. These new particles have potential applications as diverse as data storage electronics through to cancer treatment by hyperthermia (magnetically-induced heating).

Hysteresis curves of Ni and Ni@Au nanoparticles measured by vibrating sample magnetometer. Insert upper left: High temperature (~1300 °C) oven for evaporation of metals. Insert lower right: Transmission electron microscopy (TEM) image of 10 nm diameter nanoparticle.
Research Snippet #3 (Jan 14)
A New Analytical Technique to Characterise Dispersed Phases in Aerosols

Liquid and solid-like phases in atmospheric aerosol can have exotic material properties as a consequence of the presence of organic compounds and supersaturated concentrations of dissolved salts. The behaviour of these dispersed phases in aerosols cannot be predicted from the ideal examples of dilute liquids or solids, and the direct measurement of properties, such as viscosity and surface tension, has proved extremely challenging. The development of a new analytical technique in Leicester has changed the situation. The viscosity and surface tension of single aerosol droplets (with diameters from 1 to 10 µm) can now be measured across an unprecedented dynamic range; for example, viscosity can be measured from $10^{-3}$ Pa·s (dilute aqueous aerosol) to $10^{10}$ Pa·s (solid-like aerosol). The approach is based on monitoring oscillations in shape on the surface of a single aerosol droplet isolated in an optical trap. These oscillations appear on a composite droplet following the coalescence of two smaller droplets, and their amplitude and frequency are measured by recording the time-dependent intensity of elastic-scattered light.

The original concept for the method was devised by Dr Andrew Hudson, group leader in the Spectroscopy and Dynamics Group at Leicester, and Professor Jonathan Reid, group leader in Aerosol Research Centre at the University of Bristol. The research has been published recently in the flagship journal of the Royal Society of Chemistry, Chemical Science, 4, 2013, 2597-2604 (DOI: 10.1039/C3SC50682G), with an earlier communication appearing in the Journal of Physical Chemistry A, 116, 2012, 8873–8884.

(DOI: 10.1021/jp304929t). The technique will now be exploited to lead to a better understand of water transport, chemical aging, ice nucleation, optical extinction and morphology in atmospheric aerosol by characterising the material properties of kinetically arrested or metastable dispersed phases. These are major topics in environmental science.

The variation in the intensity of elastic scattered light during the binary coalescence of aerosol droplets in an optical trap. Oscillations are due to fluctuations in the shape of the composite droplet. The frequency and the time constant for decay are related to surface tension and viscosity; a model that was developed originally by Lord Rayleigh (Proc. R. Soc., 1879 29,71).

Research Snippet #4 Feb14 – The three-legged stool of Atmospheric Chemistry

Prof Paul Monks and his colleagues from the International Global Atmospheric Project have published an editorial looking at the role for laboratory studies in their science (Abbatt et al, Atmospheric Environment, 84, 2014). They state “Atmospheric chemistry has required for decades, and will require moving forward, a three-legged stool approach of laboratory, ambient observations, and modelling studies to address the most pressing issues of our time. Each leg of the stool is only as stable as the fundamental chemistry that underpins it, i.e. within each leg there is the need to
understand the connections that exist between the fundamental properties and reactivity of molecules and observable atmospheric phenomena.” The editorial sets out to underline that atmospheric chemistry is evolving in a manner whereby connections to fundamental atmospheric chemistry research are weakening and this could destabilize the approach that has worked so successfully in the past. There are many parallels to the challenge of multidisciplinary science across a number of chemical disciplines.

**Research Snippet #5 Feb14**

*At the vortex of superfluidity*

Quantized vortices are one of the hallmarks of superfluidity. However, while well known in the bulk liquid, firm evidence for quantized vortices in its nanoscale counterpart, superfluid helium droplets, is still lacking. The behaviour of quantized vortices when restricted to nanoscale dimensions raises the possibility of exploring new physics, as well as new chemistry. At the Leicester NanoLab we have recently investigated the growth of metal nanoparticles by the addition of metal atoms to superfluid helium droplets, which are then imaged using transmission electron microscopy (TEM). When silver was added we have observed chains of spherical nanoparticles with a nearly uniform inter-particle spacing. Spherical Ag nanoparticles have no intrinsic anisotropy and so these particles must be guided into position by interaction with a quantized vortex spanning the diameter of the helium droplet. This study therefore provides, for the first time, an unequivocal evidence for quantized vortex formation in nanoscale liquid helium droplets. The result has recently been accepted for publication as a communication article in PCCP (By Dr. Shengfu Yang).

**Research Snippet #6 (Feb 14)**

*Chinese Media pick-up on air pollution and climate links*

Prof Paul Monks discussed global issues surrounding the linkages between air pollution and climate change at the American Association for the Advancement of Science (AAAS) 2014 Annual Meeting in Chicago between 13-17 February – one of the largest of its kind worldwide.

During his talk on Sunday 16 February entitled ‘Air Quality and Climate Change: Science and Policy Challenges’ Professor Paul Monks from the University of Leicester’s Department of Chemistry spoke on the topical subject to a global audience, looking at the new scientific evidence around so-called “short-lived climate forcers” and assessing the growing realisation that a way to meet short-term climate change targets may be through the control of “air quality” pollutants.

The work was picked up by the Chinese media who have a great interest in air pollution issues.

In Chinese (Google translate will make English version)


**Research Snippet #7 (March 14)**

*Comparing air*

International comparison campaign starts at University of Leicester’s clear air station. As part of the work being undertaken in the JOAQUIN (www.joaquin.eu) project by the Atmospheric Chemistry team in the Department of Chemistry, a new mobile monitoring unit has been installed near the new air quality monitoring station. Over the
next month detailed measurements of particles gases will be made with a view to exploring the health effects of air pollution. As part of the deployment there will be a public event held in the City Centre on the 5th April that will allow the public to find out more about measurements and cleaner air/better health.

Previous campaigns already confirmed that the Joaquin monitoring stations in Amsterdam and Antwerp are operating correctly. The data obtained from measurements at additional sites in these cities has been very useful and we now look forward to the results in Leicester. After finishing the Leicester campaign, the mobile station will move to London and Brighton.

Joaquin is part funded by INTEREG via ERDF.

Research Snippet #8 (March 14) - Longer lasting batteries

Efficient rechargeable Zn batteries have been an important target for energy storage because Zn is abundant, inexpensive and relatively lightweight. However, Zn based rechargeable batteries have been difficult to achieve because of various technological problems including the formation of Zn dendrites during charging.

Here the University of Leicester, as a part of an international team, report a significant advance; a non-aqueous zinc–polymer secondary battery was fabricated with polyaniline as a cathode and zinc metal as an anode in an electrolyte consisting of zinc-bis(trifluoromethyl-sulfonyl) imide Zn(TFSI)$_2$ dissolved in propylene carbonate. This combines conducting polymer technologies with hybrid ionic liquids. The resultant battery was very good in extended cycle life (greater than 1700 cycles) so would be suited for many charge-discharge cycles, however, the battery was susceptible to self-discharge and so not so good for standby applications.