Report of April 2014 Meeting
Royal Society
Southern Highlands Branch

Speaker: **Professor Ken Baldwin**
Director of the ANU Energy Change Institute,
Deputy Director, Research School of Physics and Engineering, ANU

Topic: **Using Lasers to Create the Coldest Stuff in the Universe.**

Dr Baldwin opened his lecture to the 35 attendees with the comparison between the coldest place in the universe, the Boomerang Nebula (approx 1K or -272C), and the coldest man-made object, a Bose-Einstein condensate (BEC) at 0.45 nK. Even the coldest depths of space are a billion times too hot for a BEC to exist because of residual radiation from the big bang. BECs represent an entirely new state of matter not found naturally anywhere in the universe.

In 1925, based on work by Satyendra Nath Bose, Albert Einstein proposed that if one could make a collection of atoms cold enough, they would condense into a single quantum state making each atom identical to its neighbours in a similar way to photons in a laser beam. It wasn't until 70 years later that scientists were able to actually create the world's first BEC in the laboratory.

Scientists at the ANU have recently become only one of four groups in the world to develop a novel laser cooling apparatus capable of creating BECs using excited helium atoms rather than atoms in the ground state. The advantage of using excited atoms in the BEC is that they can be detected individually because they decay to their ground state on contact with a detector, the energy thereby released liberating an electron and producing a detectable signal in the process. The ANU team is hopeful that this newly commissioned system will yield vital clues to the mechanism of BEC formation.

In one of the most explicit demonstrations of wave-particle duality, Dr Baldwin described how his group had successfully guided atoms in a laser light beam, the atoms displaying the same properties as light guided in an optical fibre. The team cooled helium atoms to ultracold temperatures – just one millionth of a degree above absolute zero – then dropped them into a laser light beam focused on the atom cloud. The experiments which followed were based on analysis of speckle patterns.

Optical speckle is a well-studied property of light where, in an optic fibre, speckle is created through interactions between waves of the same frequency, but with different phases and amplitudes. These waves combine, or interfere, to create a wave with randomly varying intensity. While many other wave properties of atoms have been observed before, atomic speckle had remained elusive until Ken Baldwin and his colleagues guided atoms in a laser light to create the tell-tale grainy pattern of speckle.

Astonishing as it may seem, Professor Baldwin has now produced a DVD aimed at year 8 students throughout Australia, where the creation and properties of BECs are presented in a simplified, yet readily understandable format.

The history of physics is full of examples of strange and exotic phenomena that, having been developed out of pure curiosity, have gone on to spawn unimaginable technological advances. Lasers, X-rays and transistors all belong to this family and BECs may well be its newest member. The helium BEC project is part of the ARC Centre for Excellence for Quantum-Atom optics.

Anne Wood