A giant molecule stuns the scientists

This computer-generated image is of a strange molecule that has shocked chemists. It is as big as a bacterium and should exist in the real world according to research.

Around 200,000,000,000,000,000 conventional atoms would fit on the full stop at the end of this sentence. They are mostly empty space – the positively charged nucleus, where most mass resides, is 100,000 times smaller than the overall atom, which is a mist of negative charge, consisting of one or more electrons.

But the molecule shown here, consisting of only two atoms, is enormous – about one millionth of a metre across, about the same size as an *E-coli* bacterium.

The predictions that these fragile giants should exist have been published in the *Journal of Physics* by Edward Hamilton and Prof Chris Greene of the University of Colorado, with Dr Hossein Sadeghpour of the Harvard-Smithsonian Centre for Astrophysics in Cambridge, near Boston.

These are called "butterfly Rydberg states", where butterfly refers to the shape and state refers to the way electrons are distributed around an atom or molecule. Rydberg acknowledges pioneering work in the late 1800s by Johannes Rydberg that helped in the development of quantum mechanics.

This image shows the likelihood of finding an electron in orbit around the molecule (the peaks correspond to where it is most likely to be), calculated by the most successful theory in science, quantum mechanics.

Two years ago, Prof Greene and colleagues, including Prof Alan Dickinson of the University of Newcastle, found a novel and bizarre class of molecular states that involved electron motion that are far more complicated than previously thought. "They showed an uncanny resemblance to a trilobite, and for this reason they were dubbed trilobite states," he said.

Now the team has found a related but different butterfly Rydberg state, which once again is vast compared with conventional atoms and molecules.

Although the practical importance of this work is unclear, the finding has caused a buzz among scientists.

"The main excitement about this work in the atomic and molecular physics community has related to the fact that these huge molecules should exist and be observable, and that their electron density should exhibit amazingly rich, quantum mechanical peaks and valleys," said Prof Greene.

At least one well-known chemist has told Prof Greene that he was shocked by the work because he had thought that everything was known about the simplest molecules that consist of two atoms.

The giant molecules, which are extremely tenuous, have not yet been seen in a laboratory, but a team at the University of Connecticut is now looking for them.

"It is very difficult to observe them, because they are held together by only the tiniest conceivable attractive force, and therefore the only hope to create them is in an ultracold atom trap, held just millionths of a degree above absolute zero temperature," said Prof Greene, referring to the lowest achievable temperature of minus 273·15 C.

In other research that will lay bare new secrets of the quantum world, the inner life of atoms has been revealed for the first time.

All of chemistry boils down to the behaviour of electrons in atoms and scientists are now able to study their movements with "atomic photography", where

The giant molecule

ultrafast laser pulses are used to capture atomic processes in the same way that a speeding bullet can be "frozen" by a camera with a fast shutter.

The technique, reported in the current issue of the journal *Nature*, has been developed by Prof Ferenc Krausz of the Vienna University of Technology in Austria and colleagues, who used it to study electrons shuffling around inside a krypton atom.

For more than a decade, chemists have used pulsed lasers to reveal processes that take place in tens of femtoseconds, where a femtosecond is a thousandth of a millionth of a millionth of a second.

For atomic photography, the Austrian team, with colleagues in Germany, created pulses that last a few attoseconds, where an attosecond is a thousand times briefer, lasting a millionth of a millionth of a millionth of a second. The work heralds a new era of attophysics.

Roger Highfield