Ottawa scientists snap first image of elusive electron

World of the atom 'doesn't obey' normal laws of physics

BY TOM SPEARS

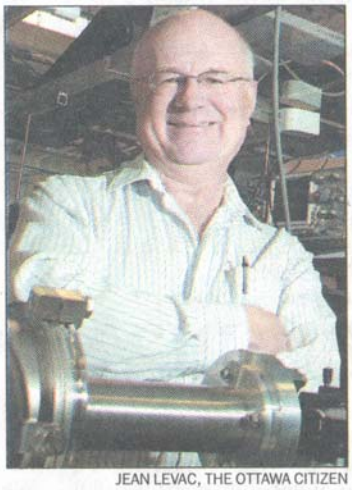
The National Research Council has made the first image ever recorded of an electron orbiting in a molecule. It's the first look inside a working atom, which usually shows up as a fuzzy round blob with no identifiable moving parts.

Watch the movement of individual electrons, say experts, and it may reveal how electrons shift around in chemical reactions.

The journal *Nature* calls it a view of "the place where chemistry happens."

But this isn't just any image, just as an electron is no ordinary piece of matter like the objects we see around us, following the laws of time and space we understand in daily life. This is quantum physics, the study of matter at its tiniest level, a field where one particle can be in many different places at the same time, where things are defined by an Uncertainty Principle, where even the experts say things like "only God can ever do that."

"It's a different world, you know. The world of the atom doesn't obey the same laws that we have sitting in our office," says David Villeneuve, the NRC scientist who leads the team that caught electrons in their orbital flights.



JEAN LEVAC, THE OTTAWA CITIZEN

David Villeneuve, a National Research Council scientist, works at the Femtosecond Lab in Ottawa.

Physicists have known how an atom is built for more than a century. There's a nucleus in the centre with protons and neutrons; and a small cloud of electrons whizzing around the outside like satellites around the Earth.

The Villeneuve group works at the NRC's Femtosecond Lab in Ottawa, named because it investigates atoms for incredibly short intervals. Think of a one followed by 15 zeroes; that's the number of femtoseconds in a second.

In this study, they examined electrons in molecules of nitrogen gas, which are just two nitrogen atoms bonded together. Molecules are easier to hold steady and examine than separate atoms.

When they bounce very short laser pulses off them, a reaction happens. The electron is briefly jolted away from its molecule and then rejoins it. This causes bursts of stronger energy — X-rays — from the molecule. And these X-ray bursts make an indirect "shadow" of where the electron is.

The next part is the most difficult to understand because it seems to defy logic. Each electron is in all the different parts of its orbit at once, like one satellite that's over Canada and China and all at the same time.

"If your car is driving somewhere, it is represented by its position and its velocity," Villeneuve says. In other words, it's at a point on a map, moving somewhere. But, "quantum mechanical things, because of the Uncertainty Principle, aren't in any one place at any one time. They're kind of spread all over the place simultaneously."

The position of each electron, therefore, "is kind of a blurry thing."

The "image" uses those bursts of X-rays and plots, mathematically, where the electron is — not in a single position, but like a car going around a racetrack that is present on all parts of the track at once.

"Wow ... That's cool," commented Rob Lipson, head of the University of Western Ontario's physics department in London. He says the observation could change the whole scale on which we see atoms — from a view of the whole atom to a view of its small parts.

It's a major change, he says, because physicists have always plotted the position of electrons in atoms as a probability, without actually seeing them.

Meanwhile, we see electrons all the time with the naked eye in everything from lightning to sparks from static electricity.

If you combined all the mathematical data together, you could plot all those points and make a physical picture, Mr. Villeneuve says. He just hasn't done so yet.

Electrons are tricky, he notes. They all look alike, and they occupy a lot of points at once. "And, if you turn your back for a second, they're allowed to change places with each other, within the Uncertainty Principle, and you would never know. So this leads to extra complications in how to determine what the (atom's) structure looks like."