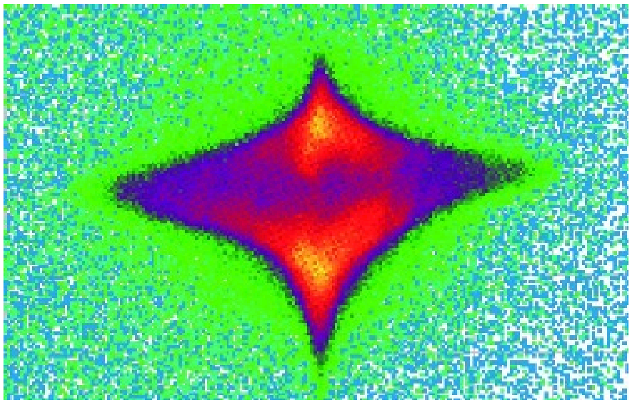
Helium atoms get the ride of their life

Oct 29, 2009 3 comments



Ponder the force Helium atoms accelerated at unprecedented rates

To the adrenaline junkie midway through a bungee jump, gravity must feel like it can accelerate matter at a spectacular rate. At the atomic scale, however, when it comes to shifting around neutral particles, gravity is incredibly ineffective compared with other fundamental interactions such as the strong and weak nuclear forces.

Now, however, a team of physicists in Germany has shown that a little-known interaction caused by electric fields known as the "ponderomotive" force can accelerate neutral particles at up to 10^{14} times the Earth's gravitational acceleration. As well as being of interest to fundamental physics, this ability to transfer large amounts of momentum to neutral particles could lead to a host of novel applications in surface science, say the researchers.

'Electrical pressure'

All students are taught at school that when objects possessing electrical charge are exposed to an electric field, these objects experience an electric force that can lead to motion. If the electric field is oscillating, however, then the charged object is then exposed to a second force that is proportional to the field-intensity gradient. Depending on the amount of matter and the scale of this intensity gradient, the ponderomotive force can have a significant effect.

Until now, however, physicists had assumed that the ponderomotive force would have a negligible effect on matter that is neutral. But, according to Ulli Eichmann and colleagues at the Max-Born Institute and the Institute for Optical and Atomic Physics in Germany, there is no reason for this to be the case. These researchers argue that the effect is largely independent of charge and they designed an experiment to demonstrate the magnitude of the effect on neutral matter.

The physicists began by aiming a beam of helium atoms at a detector, before firing a series of laser pulses at the beam so that individual atoms were exposed to a localized electromagnetic field. Then, by analysing data from their position-sensitive detector, they were able to show that at least one per cent of the helium atoms had undergone an acceleration, and in some cases this was as much as 10^{14} times that of the Earth's gravitational acceleration (9.8 m $^{s-1}$.

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To explain the mechanism of this acceleration, Eichmann and colleagues refer to a model that they put forward in a paper last year. When the atoms are exposed to a laser pulse, an electron can gain energy from the laser field, causing it to be briefly "liberated" from the atom. However, this surge of energy is not sufficient for the electron to break free entirely from the Coulomb forces and it is recaptured so that it sits a long way from the nucleus in what is known as a "Rydberg state".

It is in this state that the atom is subject to the ponderomotive force and the "quivering" electron can drag the entire atom in the direction of the localized electric field. Fortunately for the researchers, this state was long-lived enough for them to locate the positions of helium atoms at the detector and thus rule out other effects that could have caused a beam of neutral particles to be deflected and spread.

Eichmann told *physicsworld.com* that he can envisage applications resulting from the "instantaneous" transfer of momentum to an atom. An example of this might be the accurate and efficient deposition of atoms on surfaces for optical applications. "Atoms may be steered by manipulating the spatial geometry of the laser fields," he says.

Robert Jones, an atomic physicist at the University of Virginia in the US is impressed by the new research. "The possibility of controlled interactions between atoms or molecules through precisely timed collisions at well-defined relative velocities is particularly intriguing," he told *physicsworld.com*.

This research is published in this week's issue of *Nature*.

About the author

James Dacey is a reporter for *physicsworld.com*

3 comments

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1 **GrahamRounce**
Oct 30, 2009 9:32 AM
London, United Kingdom

Maybe you'd like to explain again how this works.

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2 **jmcaneney**
Oct 30, 2009 1:04 PM
BANGOR, United Kingdom

A Typo

When I went to school, the units for the acceleration of gravity was m/s^2 not m/s as the article indicates. I think a typo has occurred.

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3 **ASIWEL**
Nov 1, 2009 6:41 PM
Kalamazoo, United States

Amazing

I am constantly amazed at the extent of really neat new ideas and empirical phenomena that arise when old, common-place, well-accepted (and "understood") notions get re-examined a bit more closely with "21st century" technologies. What pleasant surprises ensue! Consider this idea here: An ability to convey large accelerations to "neutral" particles. Next step, who knows, might be to add this to a "rocket engine" that does not depend on ionic acceleration or to help speed up a neutral particle beam.

One assumes that this observed ponderomotive acceleration effect is directional and can be controlled ... i.e. the particles do not simply oscillate in place? The experiment described more or less depends on this ability to deflect a little bit at least. It rather looks like a sort of tugging on the surface of a neutral sphere to temporarily create a charge asymetry that can "pull" (or be pulled on?). This electron is sort of quantum teleported a little bit away from the atom by the energy in the laser beam? Then "recaptured." Sir Newton might wonder why the electron doesn't move equally and oppositely back toward the atom? It probably does, but the net shift in the center of gravity of the atom over time would be an acceleration ... rather neat, like "instantly" repositioning the end of a free-floating, unattached but stretched, rubber band.

Edited by ASIWEL on Nov 1, 2009 7:14 PM.

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