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Doppler effect: a variation in the infinitely small

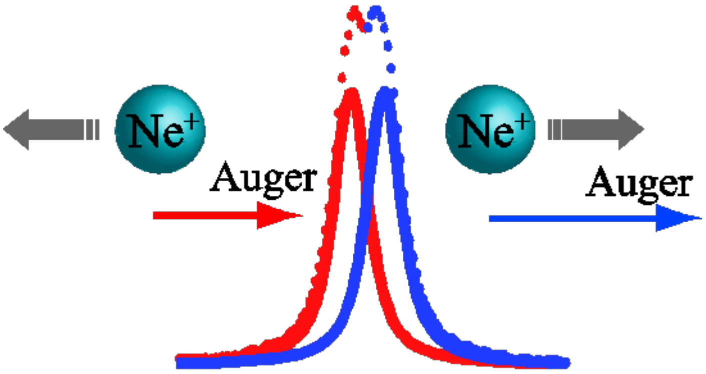
Thanks to an experimental setup unique in the world, a team of researchers from the Laboratory of Physical Chemistry - Matter and Radiation (UMPC /CNRS), the Free University of Berlin in Germany, Uppsala University in Sweden and the SOLEIL Synchrotron, have just shown, microscopically, the importance of the Doppler effect, a phenomenon better known on a macroscopic scale. In their study, published in Nature Communications, they were interested in high-energy electron emissions from single atoms.

We have all probably noticed that when an ambulance approaches with its siren blaring, the sound is at a higher pitch than when it moves away; this is the famous Doppler effect. It works equally well with any moving wave-emitting object! This includes sound waves, but also electromagnetic waves, used by radar detectors to measure the speed of a car, for example, or for calculating the distance to a star using the color of light it emits.
Is such a phenomenon limited to the macroscopic world?

In order to find out, the right tools are required. These are now available, thanks to a study by researchers at the Laboratory of Physical Chemistry-Matter and Radiation (UMPC / CNRS), the Free University of Berlin in Germany, Uppsala University in Sweden and the SOLEIL synchrotron (GALAXIES beamline) on the Saclay campus.

In practice, the object studied was an atom. Researchers selected atoms of a rare gas, neon. The "game" was to target the atom with a particle of light, or photon, having a very specific energy, so that the atom absorbed the photon. This is the photoelectric effect discovered by Einstein in 1905, resulting in an electron being ejected from the atom. This causes a backward movement of the atom, in a direction opposite to that of the electron, as with a gun firing a bullet. Then, following a characteristic cascade of reactions in the atom, further electrons will in turn be expelled. These so called "Auger electrons" are emitted in a secondary phase by the atom on the move. However, at the atomic level, electrons behave like waves, following the well-known principle of wave-particle duality, and it is these electrons that are behind the microscopic Doppler effect highlighted in this study.

The scientists used a new analyzer at the SOLEIL synchrotron which carefully measures Auger electron energy emitted in a given direction. However, these electrons may come from atoms that are moving either towards the detector or in the opposite direction. Because of the Doppler effect, the electrons detected by the analyzer will have a different energy depending on the movement of the atoms. With a less powerful experimental setup, it would be impossible to distinguish these electrons. Here the researchers were able to observe the Doppler effect in the form of a gradual broadening, then a duplication of the recorded signal, as a function of the increase in energy of the absorbed photons (high energy X-rays) and of the electrons emitted by the neon atoms. The figure below describes the observed effect.



Representation of Doppler effect

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This Atomic Auger Doppler effect is a general phenomenon that must now be taken into account in so-called high-energy photoemission experiments, such as that described here for isolated atoms or molecules, but also when measuring solids, such as semiconductors, and in the characterization of new materials at the microscopic scale.

Bibliography

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