Mysterious X-ray signal does not originate from dark matter

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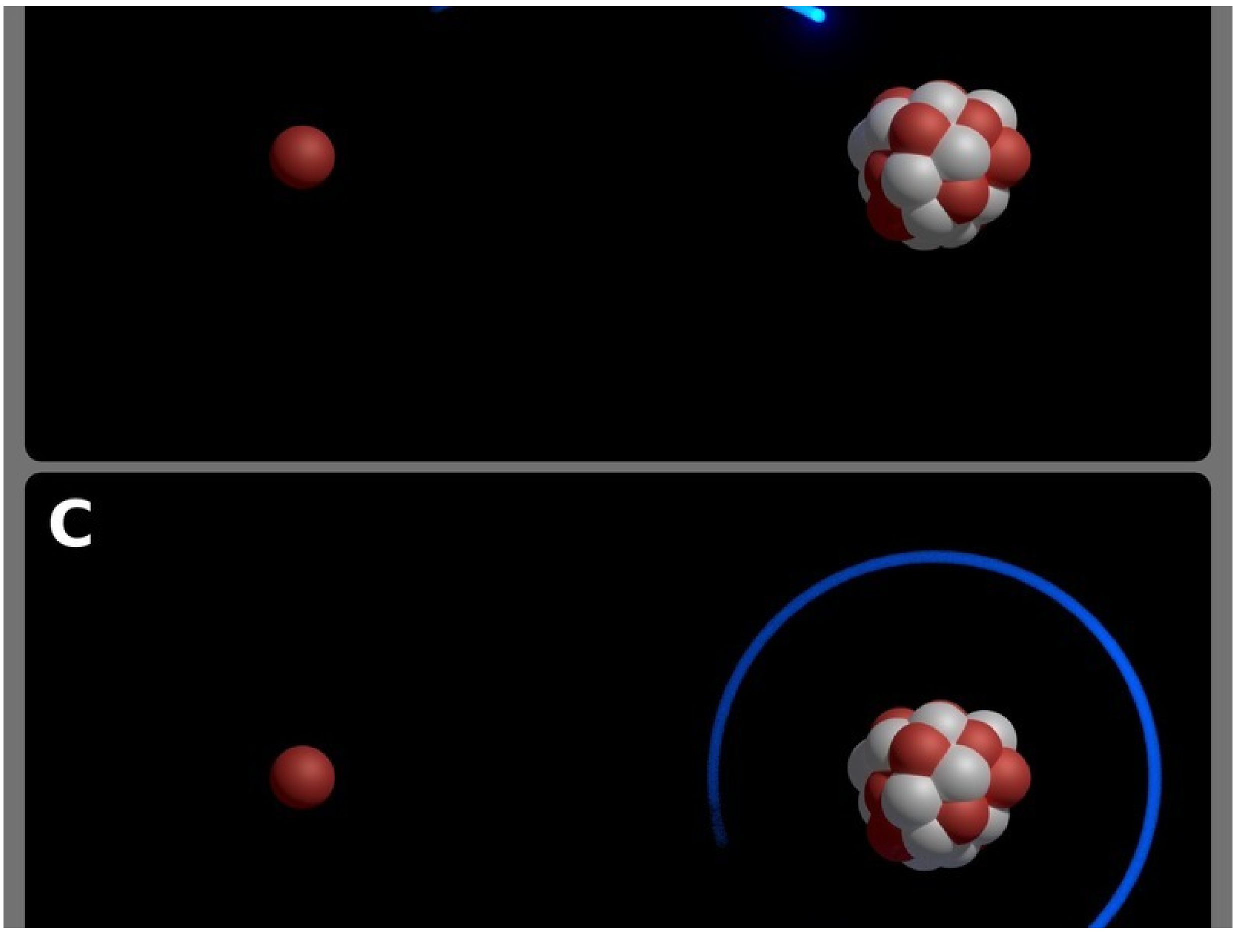

Charge exchange instead of dark matter: An X-ray signal from clusters of galaxies, which researchers have so far not been able to explain, could be produced when highly charged sulfur captures an electron. A sulfur nucleus (S16+) approaches a hydrogen atom (A) and attracts the electron (B), which ends up in a high energy level of S15+ (C) before falling back into the ground state (D), emitting X-rays as it does so. Credit: Max Planck Society

A mysterious X-ray signal from clusters of galaxies recently caused some excitement among astronomers: Does it perhaps originate from dark matter, which makes up around 80 percent of the matter in the universe, but which scientists have not yet been able to detect? In order to help answering this question, physicists at the Max Planck Institute for Nuclear Physics in Heidelberg checked an alternative explanation. Accordingly, the search for this form of matter, which is difficult to detect, must go on, as the mysterious X-ray signal seems to originate from highly charged sulfur ions that capture electrons from hydrogen atoms.

Around two years ago, the XMM-Newton X-ray satellite radioed data back to Earth which fired up great hopes with astrophysicists. It had picked up weak radiation from several galaxy clusters at an energy of around 3.5 kiloelectronvolts (keV) which the researchers were not immediately able to explain with the aid of the known X-ray spectra. Speculation quickly arose that they could be signals of decaying particles of dark matter – this would have been the first concrete trace of the long-sought form of matter. Hope was soon dampened, however: The regions in which XMM-Newton observed the X-ray radiation did not match the spatial distribution which astrophysical analyses predicted for dark matter.

In addition, there are still a large number of physical processes for which astronomers do not know the corresponding fingerprints in X-ray spectra, and so cannot yet be excluded as the possible cause of the mysterious signal. Fact is, the spectral data in the collection of tables which researchers use to evaluate astronomical spectra are still incomplete. They are sometimes based on theoretical assumptions and are correspondingly unreliable.

Highly charged ions can frequently be found between the galaxies

Physicists working with José Crespo, Leader of a Research Group at the Max Planck Institute for Nuclear Physics, have now closed one gap in the X-ray data with their experiments. They thereby support a suggestion made by their Dutch cooperation partners Liyi Gu and Jelle Kaastra as to what the cause of the X-rays could be. According to computations done by the two researchers from SRON, Netherlands Institute for Space Research, the mysterious line could be caused by bare sulfur nuclei (S^{16+}), i.e. sulfur atoms that have lost all their electrons, each of which picks up one electron from a hydrogen atom.

Highly charged ions can often be found in the hot medium between the galaxies of a cluster, and sufficient completely ionized sulfur is present as well. "Explained in illustrative terms, the charge exchange operates like this," says José Crespo in explanation of the process: "The high charge of the S16+ ion sort of sucks in the electron of the H atom. It then releases energy in the form of X-rays."

Experiments in an electron beam ion trap

The physicists used an electron beam ion trap for the measurements. First, they injected an extremely thin beam of a volatile sulfur compound into the vacuum of the apparatus. The electrons with which they then bombarded the molecules fragmented the molecules and knocked the electrons out of the atoms – how many depends on the energy of the electron beam. They can thus specifically produce the highly charged sulfur ions desired.

The researchers then switched off the electron beam for a few seconds in order to be able to observe how bare sulfur ions suck electrons from molecules which have not yet been destroyed. The electrons initially have a large amount of energy when they are captured by the S^{16+} ions, but release this energy in the form of X-rays. The most energetic of these emissions was at around 3.47 kiloelectronvolts – i.e. quite near the mysterious line which XMM-Newton had recorded. "In order to support our interpretation, our colleagues from the Netherlands have carried out model computations on the charge exchange, and they can explain our data very well," says Chintan Shah, who made crucial contributions to the experiments.

The search for dark matter must go on

The fact that the bare sulfur ions removed the electrons from intact molecules of the volatile sulfur compound and not from hydrogen atoms in the experiments carried out in Heidelberg, is not important for the X-ray spectrum, as X-rays are only generated when the electrons in the sulfur lose energy. "If the inaccuracies of the astrophysical measurements and the experimental uncertainties are taken into account, it becomes clear that the charge exchange between bare sulfur and hydrogen atoms can outstandingly explain the mysterious signal at around 3.5 keV," explains José Crespo, in summary of the result. The search for dark matter must therefore go on.

More information: Laboratory measurements compellingly support charge-exchange mechanism for the 'dark matter' ~3.5 keV X-ray line. arxiv.org/abs/1608.04751

Provided by Max Planck Society