AI helps distinguish dark matter from cosmic noise

September 6 2024

Credit: Scott Lord from Pexels

Dark matter is the invisible force holding the universe together—or so we think. It makes up about 85% of all matter and around 27% of the universe's contents, but since we can't see it directly, we have to study its gravitational effects on galaxies and other cosmic structures. Despite decades of research, the true nature of dark matter remains one of science's most elusive questions.

According to a leading theory, dark matter might be a type of particle that barely interacts with anything else, except through gravity. But some scientists believe these particles could occasionally interact with each other, a phenomenon known as self-interaction. Detecting such interactions would offer crucial clues about dark matter's properties.

However, distinguishing the subtle signs of dark matter self-interactions from other cosmic effects, like those caused by active galactic nuclei (AGN)—the supermassive black holes at the centers of galaxies—has been a major challenge. AGN feedback can push matter around in ways that are similar to the effects of dark matter, making it difficult to tell the two apart.

In a significant step forward, astronomer David Harvey at EPFL's Laboratory of Astrophysics has developed a deep-learning algorithm that can untangle these complex signals. The research is published in *Nature Astronomy*.

Their AI-based method is designed to differentiate between the effects of dark matter self-interactions and those of AGN feedback by analyzing images of galaxy clusters—vast collections of galaxies bound together by gravity. The innovation promises to greatly enhance the precision of dark matter studies.

Harvey trained a Convolutional Neural Network (CNN), a type of AI that is particularly good at recognizing patterns in images, with images from the BAHAMAS-SIDM project, which models galaxy clusters under different dark matter and AGN feedback scenarios. By being fed thousands of simulated galaxy cluster images, the CNN learned to distinguish between the signals caused by dark matter self-interactions and those caused by AGN feedback.

Among the various CNN architectures tested, the most complex—dubbed "Inception"—proved to also be the most accurate. The AI was trained on two primary dark matter scenarios, featuring different levels of self-interaction, and validated on additional models, including a more complex, velocity-dependent dark matter model.

Inception achieved an impressive accuracy of 80% under ideal conditions, effectively identifying whether galaxy clusters were influenced by self-interacting dark matter or AGN feedback. It maintained its high performance even when the researchers introduced realistic observational noise that mimics the kind of data we expect from future telescopes like Euclid.

What this means is that Inception, and the AI approach more generally, could prove incredibly useful for analyzing the massive amounts of data we collect from space. Moreover, the AI's ability to handle unseen data indicates that it's adaptable and reliable, making it a promising tool for future dark matter research.

AI-based approaches like Inception could significantly impact our understanding of what dark matter actually is. As new telescopes gather unprecedented amounts of data, this method will help scientists sift through it quickly and accurately, potentially revealing the true nature of dark matter.

More information: A deep-learning algorithm to disentangle self-interacting dark matter and AGN feedback models, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02322-8

Provided by Ecole Polytechnique Federale de Lausanne