Unravelling the Mystery of the Big Bang

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*Researchers at the University of Malta are developing new ways to study the universe by mimicking processes that occur in the human brain. The **CosmicLearning** project involves creating artificial neural networks (ANNs) to understand how the universe is expanding and, in the process, reframing how astrophysicists study the cosmos.*

What pops up in your mind when you hear the words 'machine learning'? A robot sitting at a desk? A row of computer chips with beeping noises and flashing lights? Or perhaps an amorphous shape – a kind of magic genie? Machine learning is an ever-present concept in our daily lives, employed in a wide range of technologies: from facial recognition, to voice-to-text functionalities in our smartphones. Yet, we hardly understand what it means, what it can do and how it is applied in technology and science. **THINK** spoke with the researchers behind the CosmicLearning project at UM to find out what machine learning is, and how it can be used to create better predictive models of our universe.

WHAT CAN MACHINE LEARNING DO FOR YOU?

Machine learning is a type of artificial intelligence. A Google search will tell you that a machine learning model is created through the analysis of data by a program. The more data is fed into the programme, the more accurate the machine learning model becomes. As research support officer Dr Rebecca Briffa explains, machine learning models 'learn patterns from the data without being explicitly programmed to do so'.

Machine learning identifies patterns that enable machines to do certain tasks with accurate results. Ever scrolled through Facebook and seen an advertisement about something you were just discussing with your co-worker? That's machine learning – analysing your data and identifying patterns in what you might like.

The team behind CosmicLearning – including Briffa, Dr Jurgen Mifsud, and principal investigator Prof. Jackson Said from UM's Institute of Space Sciences and Astronomy – is using this technology to untangle the history of the universe, specifically to determine how it is expanding.

THE BIG BANG THEORY AND ALL THAT CAME AFTERWARDS

In 1929, Edwin Hubble proved that the universe is expanding. In 2011, the Nobel Prize-winning physicists Saul Perlmutter, Brian P. Schmidt, and Adam G. Riess discovered that not only is the universe expanding, but the rate of expansion is increasing.

Much of the research done on the universe, its expansion, and its future relies on statistical models. The most prevalent of these, the Standard Model of Cosmology (SMC), assumes that 'the universe was created in the "Big Bang" from pure energy, and is now composed of about 5% ordinary matter, 27% dark matter, and 68% dark energy'. Dark matter sustains the structure of galaxies, while dark energy appears to be responsible for the universe's accelerating expansion.

However, no model is perfect, and current empirical observations seem to contradict the long-standing SMC. Not only do direct observations of dark matter continue to elude scientists, but, according to Said, the universe is also expanding at a faster rate than the model predicts. This discrepancy between observed and calculated results is what physicists refer to as cosmic tension. The CosmicLearning project is attempting to solve this tension using machine learning – more specifically with artificial neural networks (ANNs).

WHEN PHYSICS MIMICS THE BRAIN

ANNs are machine learning methods inspired by the structure of animal brains – specifically how neurons are organised into layers and communicate with one another. The team believes that ANNs offer a superior approach for studying the expansion of the universe compared with other methods. They make fewer assumptions and are more adaptable when interpreting new data, leading to more accurate results. ANNs are also able to infer correct data for different time points of the universe – from billions of years ago to the present-day universe – and can even be used to calibrate other indicators of universe expansion.

As Mifsud explains, 'The team constructed the ANN model using observational data, and the resulting ANN was then tested with the same data.' The datasets collected through direct observations – in this case, cosmic expansion data and data related to the growth of large-scale structure – are both related to the expansion of the universe. While cosmic expansion data tracks how the universe stretches, large-scale structure data examines how matter clusters together.

The challenge was getting the ANN to reconstruct the same information that was used to train it. The group successfully showed that the ANN model is more

effective at recreating empirical data than currently used models.

Besides solving a long-lasting cosmic tension, the research will open doors to novel ways of developing models around data. While traditional cosmological models are built upon statistical predictions, this innovative approach by the CosmicLearning team aims to use existing empirical data to create a model that mimics the natural processes that generated it.

WHAT WAS I MADE FOR?

The ultimate aim is not only to develop a new model capable of explaining and predicting the universe's rate of expansion, but also to serve as a proof of concept demonstrating that ANNs can be used to build new models across different fields – from astrophysics to health. This promises to create adaptable frameworks that help scientists better understand natural phenomena and tailor solutions to specific issues.

With vast datasets available, astrophysics is the ideal starting point for training this type of machine learning. Particularly in astrophysics, having a new predictive model for cosmic expansion may help answer one of the oldest philosophical questions: where, and how, did the universe originate? 'Just as Einstein's theory of relativity would, decades later, help create GPS systems, this knowledge may very well shape our future technologies,' remarks Prof. Said.

The team emphasises the value of intradisciplinary collaboration throughout the process, with Briffa noting that, 'Collaboration with people gives a fresh perspective'. This view aligns with the team's objective of developing toolkits that can be used by researchers from diverse disciplines, encouraging the use of ANNs in predictive modelling. Mifsud concludes, 'it is important to collaborate with people who are working with similar models and datasets, so they can exchange tips and knowledge.' T

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Further Reading

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Mukherjee, P., Said, J. L. & Mifsud, J. (2022). Neural network reconstruction of H'(z) and its application in teleparallel gravity. *Journal of Cosmology and Astroparticle Physics*, 2022(12), 029. https://doi.org/10.1088/1475-7516/2022/12/029