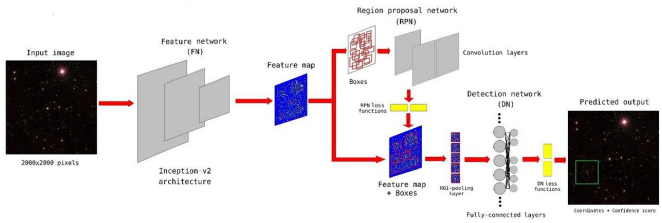
Deep-CEE: The AI deep learning tool helping astronomers explore deep space

3 July 2019



A diagram showing a high-level overview of the Deep-CEE model architecture. This novel deep learning tool has been designed to help find galaxy clusters. Credit: M. C. Chan & J. P. Stott, *MNRAS* submitted and based on Ren et al. 2015

Galaxy clusters are some of the most massive structures in the cosmos, but despite being millions of lightyears across, they can still be hard to spot. Researchers at Lancaster University have turned to artificial intelligence for assistance, developing "Deep-CEE" (Deep Learning for Galaxy Cluster Extraction and Evaluation), a novel deep learning technique to speed up the process of finding them. Matthew Chan, a Ph.D. student at Lancaster University, is presenting this work at the Royal Astronomical Society's National Astronomy meeting on 4 July at 3:45pm in the Machine Learning in Astrophysics session.

Most galaxies in the universe live in low-density environments known as "the field", or in small groups, like the one that contains our Milky Way and Andromeda. Galaxy clusters are rarer, but they represent the most extreme environments that galaxies can live in and studying them can help us better understand dark matter and dark energy.

During 1950s the pioneer of galaxy cluster-finding, astronomer George Abell, spent many years searching for galaxy clusters by eye, using a magnifying lens and photographic plates to locate them. Abell manually analysed around 2,000 photographic plates, looking for visual signatures the of galaxy clusters, and detailing the astronomical coordinates of the dense regions of galaxies. His work resulted in the 'Abell catalogue' of galaxy clusters found in the northern hemisphere .

Deep-CEE builds on Abell's approach for identifying galaxy clusters but replaces the astronomer with an AI model that has been trained to "look" at colour images and identify galaxy clusters. It is a state-of-the-art model based on neural networks, which are designed to mimic the way a human brain learns to recognise objects by activating specific neurons when visualizing distinctive patterns and colours.

Chan trained the AI by repeatedly showing it examples of known, labelled, objects in images until the algorithm is able to learn to associate objects on its own. Then ran a pilot study to test the algorithm's ability to identify and classify galaxy clusters in images that contain many other astronomical objects.

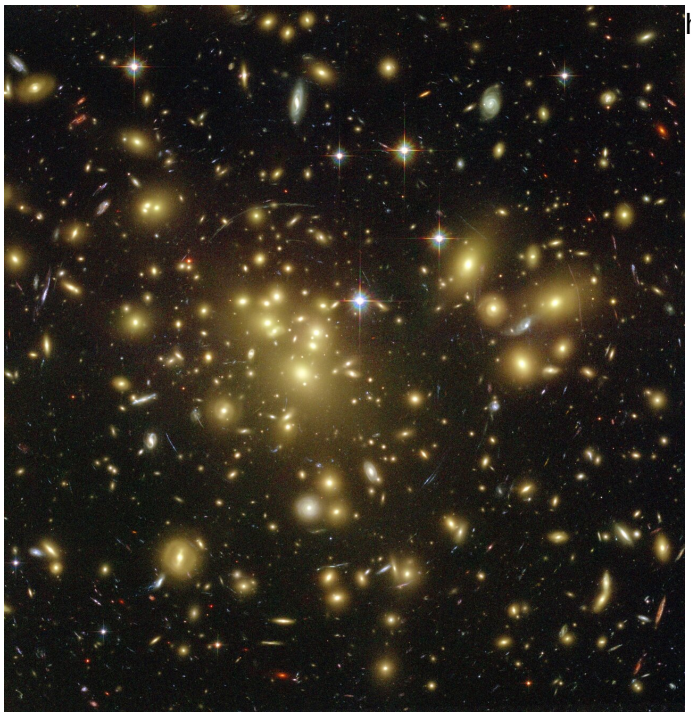


Image showing the galaxy cluster Abell1689. The novel deep learning tool Deep-CEE has been developed to speed up the process of finding galaxy clusters such as this one, and takes inspiration in its approach from the pioneer of galaxy cluster finding, George Abell, who manually searched thousands of photographic plates in the 1950s. Credit: NASA/ESA

"We have successfully applied Deep-CEE to the Sloan Digital Sky Survey" says Chan, "ultimately, we will run our model on revolutionary surveys such as the Large Synoptic Survey telescope (LSST) that will probe wider and deeper into regions of the Universe never before explored.

New state-of-the-art telescopes have enabled astronomers to observe wider and deeper than ever before, such as studying the large-scale structure of the universe and mapping its vast undiscovered content.

By automating the discovery process, scientists can quickly scan sets of images, and return precise predictions with minimal human interaction. This will be essential for analysing data in future. The upcoming LSST sky survey (due to come online in 2021) will image the skies of the entire southern hemisphere, generating an estimated 15 TB of data every night.

"Data mining techniques such as deep learning will help us to analyse the enormous outputs of modern telescopes" says Dr. John Stott (Chan's Ph.D. supervisor). "We expect our method to find thousands of clusters never seen before by science".

Chan will present the findings of his paper "Fishing for galaxy clusters with "Deep-CEE" neural nets" on 4 July at 3:45pm in the 'Machine Learning in Astrophysics' session. (Chan and Stott 2019) which has been submitted to *MNRAS* and can be found on *Arxiv*.

More information: Deep-CEE I: Fishing for Galaxy Clusters with Deep Neural Nets, arXiv:1906.08784 [astro-ph.GA] arxiv.org/abs/1906.08784

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