First Name	Surname	Proposed Talk Title	Area of Astronomy Research	Areas of Machine Learning / AI	Abstract
Ashley	Spindler	Unsupervised Classification for Galaxy Morphology. Where do computers go wrong?	Extragalactic Astronomy	Unsupervised Learning, Bayesian Inference	I will present AstroVaDEr, a variational autoencoder designed to perform unsupervised clustering and synthetic image generation using astronomical imaging catalogues. By implementing Variational Deep Embedding with a convolutional autoencoder, I will demonstrate how a classification scheme derived from a Gaussian Mixture Model can be trained simultaneously with the ability to randomly sample and generate new images, using a training set of greyscaled gri images from the Sloan Digital Sky Survey. The learned clustering model performs admirably, and is able to identify broad categories of morphological parameters such as axis-ratio, surface brightness profiles and orientation, but struggles when dealing with complex features such as the prescence of companion objects. I will show how these difficulties arise, and explore the implications for the field of morphological classification as a whole. I will then demonstrate the generative properties of the network, which can be used to synthesise new images from the learned GMM.
Clár-Bríd	Tohill	Measuring the structure of high-redshift galaxies with deep learning	Galaxies, galaxy morphology	Deep learning, supervised learning	At high redshift, due to both observational limitations and the variety of galaxy morphologies in the early universe, measuring galaxy structure can be challenging. Non-parametric measurements such as the CAS system have thus become an important tool due to both their model-independent nature and their utility as a straightforward computational process. With multiple 'Big Data' surveys planned in the near future, it will become computationally infeasible to use current algorithms to compute these parameters. One solution to this problem is to use machine learning. In this talk we present how deep learning, specifically Convolutional Neural Networks (CNNs) can be utilised to reproduce these parameters at a much faster rate. We will also discuss how Bayesian Optimisation can be applied to select suitable network architectures for this problem. This approach shows the potential of employing neural networks to future surveys to provide superior results in substantially less time.
Mike	Walmsley	Galaxy Zoo DECaLS: Detailed Visual Morphology Measurements from Volunteers and Deep Learning for 314,000 Galaxies	Extragalactic (optical and radio), fast radio bursts	Computer vision, Bayesian deep learning, active learning	Bayesian deep learning addresses two common challenges for machine learning in astronomy: learning from uncertain data and making predictions with well-calibrated error bars. I present a novel Bayesian approach used for Galaxy Zoo DECaLS, a new catalogue of detailed visual morphological classifications for galaxies imaged by the Dark Energy Camera Legacy Survey. DECaLS images reveal spiral arms, weak bars, and tidal features not previously visible in shallower SDSS images. Such features are scientifically valuable but challenging to classify automatically. I trained an ensemble of Bayesian convolutional neural networks to predict posteriors for the detailed morphology of 314,000 DECaLS galaxies. The Bayesian networks efficiently learn from uncertain (heteroskedastic) volunteer responses without the need for "clean" training samples. They can also flexibly express their own uncertainty when making predictions. Each model predicts volunteer responses for every question, learning a shared representation across questions. The networks were trained using 7.5 million individual classifications by Galaxy Zoo volunteers. When measured against confident volunteer classifications, the trained networks are approximately 99% accurate on every question. Both human and automated classifications are publicly available at https://zenodo.org/record/4196267. The automated classifications are visualised at http://bit.ly/decals_viz.
Xinyue	Sheng	Developing Rapid Classification Algorithms for Identifying Quasars in Time-series Data	time-domain astronomy	Recurrent neural networks	Motivation: Given the prove that Binary Black Hole (BBH) mergers generating gravitational waves (GW) often reside in quasars,Äô accretion disks, the motivation for this project is to apply Machine Learning techniques to efficiently recognise quasars among all possible GW sources, thus helping astronomers target precious transient events quickly Methods: Developed and trained multiple Recurrent Neural Network classifiers to specifically recognise quasars purely based on light curves using over 40,000 SDSS Stripe 82 samples; Invented three efficient and effective input formats (Group, Season, and Simple) considering light curves' observation cadence and stochastic characteristic of quasars,Äô variability, which can be referenced in future surveys, such as LSST; Compared the sensitivity of multiple bands in distinguishing quasars and non-quasars; Compared three input formats,Äô performance in classification and training efficiency; Compared different RNN architectures,Äô performance. Conclusions: This research gives a quantifiable way forward for the observational strategy and analysis for quasars in the LSST data stream.
Davide	Gerosa	Detectability of gravitational-wave signals with neural-network classifiers	Gravitational wave astronomy	Neural networks, classification, TensorFlow	We present a novel machine-learning approach to estimate selection effects in gravitational-wave observations. Using techniques similar to those commonly employed in image classification and pattern recognition, we train a series of neural-network classifiers to predict the LIGO/Virgo detectability of gravitational-wave signals from compact-binary mergers. We include the effect of spin precession, higher-order modes, and multiple detectors and show that their omission, as it is common in large population studies, tends to overestimate the inferred merger rate in selected regions of the parameter space. Although here we train our classifiers using a simple signal-to-noise ratio threshold, our approach is ready to be used in conjunction with full pipeline injections, thus paving the way toward including actual distributions of astrophysical and noise triggers into gravitational-wave population analyses.
Lynge	Lauritsen	Super-resolving Herschel SPIRE images using Convolutional Neural Networks	Submm Galaxies	Convolutional Neural Networks	Wide-field sub-millimetre surveys have driven many major advances in galaxy evolution in the past decade, but without extensive follow-ups the coarse angular resolution of these surveys limits the science exploitation. This has driven many deconvolution efforts. Generative Adversarial Networks have already been used to attempt deconvolutions on optical data. In this talk I will present an autoencoder with a novel loss function to overcome this problem at submm wavelengths. This approach is successfully demonstrated on Herschel SPIRE COSMOS data, with the super-resolving target being the JCMT SCUBA-2 observations of the same field. We reproduce the JCMT SCUBA-2 images with surprisingly high fidelity, and quantify the point source flux constraints using this autoencoder.
Peter	Hurley	HELPing Solve Confusion through probabilisitic programming	Extragalatic FIR,	Probabilisitic Programming	The recent developments of probabilisitic programming languages such as Stan, PyMC and numpyro are enabling researchers to confront observational data with more complex, hierarchical probabilisitic models. As part of the HELP project, we used Stan to build probabilistic models to infer FIR fluxes from Herschel maps. With Google's recent JAX library, and numpyro, we can now go further and incorporate SED DeepNet emulators into our probabilisitic models. Doing so opens up a wide range of interesting avenues to explore, such as inferring relations such as the starformation rate density and FIR relation directly from the maps, thereby using all of the constraining power of the FIR data. In this talk, I will give an overview of the capabilities of numpyro and JAX, and provide a case study on how we are using it to study extreme starformation candidates.

Vasileios	Skliris	Detecting the Unmodelled GW Signals with Machine Learning	Gravitational Waves	CNN, Timeseries classification	Convolutional Neural Networks (CNNs) have demonstrated potential for the real-time analysis of data from gravitational-wave detector networks for the specific case of signals from coalescing compact-object binaries such as black-hole binaries. Unfortunately, training these CNNs requires a precise model of the target signal; they are therefore not applicable to a wide class of potential gravitational-wave sources, such as core-collapse supernovae and long gamma-ray bursts, where unknown physics or computational limitations prevent the development of comprehensive signal models. I will demonstrate the development of a CNN based algorithm with the ability to detect generic signals -- those without a precise model -- with sensitivity across a wide parameter space. This algorithm has a novel structure that uses both the network strain data and the Pearson cross-correlation between detectors to distinguish correlated gravitational-wave signals from uncorrelated noise transients. The efficacy of this CNN is demonstrated using real LIGO-Virgo observational data, and show that it has sensitivity comparable to that of ``gold-standard'' transient searches currently used by LIGO-Virgo, at extremely low latency and using only a fraction of the computing power required by existing searches, making possible the true real-time detection of gravitational-wave transients associated with gamma-ray bursts, core-collapse supernovae, and other relativistic astrophysical phenomena.
Joshua	Wilde	Do Neural Networks Dream of Gravitational Lenses: Using CNN to Identify Gravitational Lenses & How They Do It	Gravitational Lensing	CNN	In preparation for future large surveys such as LSST and Euclid. These expect to find more than 10^5 gravitational lenses, I am interested in making sure the novel systems are discovered as these offer greater constraints on dark matter. I have been developing a CNN model to identify gravitational lenses from simulated Euclid images. This CNN model performs well with an F1 score of 0.98, but why? I have applied several approaches including deep dream, occlusion maps, and class generated images to understand the aspects of the image which influences the model,Äôs classification. Currently I am creating images of compound lenses to understand how well my model performs on data of rare lens configurations.
Thomas	Chen	Using Deep Neural Networks to Locate Mini-Filament Eruptions	solar-terrestrial physics; solar events	computer vision; deep learning; convolutional neural network; image processing; semantic segmentation	Small-scale filament eruptions on the sun have previously been documented in the scientific literature. However, robust techniques to identify and semantically segment them in imagery data have not been developed. In this talk, we outline preliminary work in using deep learning algorithms, and convolutional neural networks particularly, to locate mini-filament eruptions. We train a ResNet50 architecture model on H-alpha data, using cross-entropy loss as the criterion for optimization and an Adam optimizer with a learning rate of 0.01. The primary long-term objective of this work is to find correlations between the occurrences of these eruptions and coronal jets. Automated computer vision methods provide more efficient mechanisms to study long term trends and correlations that would not be possible with conventional methods.
John	Armstrong	Learning the Flaring Atmosphere of the Sun	Solar Physics	Deep Learning, invertible neural networks	During a solar flare, it is believed that reconnection takes place in the corona followed by fast energy transport to the chromosphere. The resulting intense heating strongly disturbs the chromospheric structure and induces complex radiation hydrodynamic effects. Interpreting the physics of the flaring solar atmosphere is one of the most challenging tasks in solar physics. Here we present a novel deep-learning approach, an invertible neural network, to understanding the chromospheric physics of a flaring solar atmosphere via the inversion of observed solar line profiles in HŒ± and Ca ii Œª8542. Our network is trained using flare simulations from the 1D radiation hydrodynamic code RADYN as the expected atmosphere and line profile. This model is then applied to single pixels from an observation of an M1.1 solar flare taken with the Swedish 1 m Solar Telescope/CRisp Imaging SpectroPolarimeter instrument just after the flare onset. The inverted atmospheres obtained from observations provide physical information on the electron number density, temperature, and bulk velocity flow of the plasma throughout the solar atmosphere. The density and temperature profiles appear consistent with the expected atmospheric response, and the bulk plasma velocity provides the gradients needed to produce the broad spectral lines while also predicting the expected chromospheric evaporation from flare heating.
Amanda	Ibsen	Early classification of supernovae light curves	transient astronomy	time series classification	There is a growing interest within the scientific community to find solutions to the problem of automatic classification of light curves for different astronomical events, as the SPC Challenge held in 2010 and the PLAsTiCC challenge held in 2018 have shown us. Supernovae are the trickiest type of event to tell apart, simply because their light curves are too similar in shape to one another. However, photometry is the most easily acquired information about supernovae, and the upcoming wide-field surveys will make it possible to obtain observations of a large sample of transients. Since explosive transients are a one time event and they fade after a while, it is important to catch them early enough to be able to make follow-up observations. In the following work, we compare different methods for early classification (classification of the light curves when the explosion hasn,Äôt happened yet) and find that, although they all perform similarly to one another over simulated data, self-attention improves classification results when there is a marked difference between the training set (simulated data) and the test set (real light curves).
Thomas	Killestein	Transient-optimised source classification in difference imaging with Bayesian convolutional neural networks	time-domain astronomy, transients, supernovae, large-scale sky surveys, multi-messenger astrophysics	image classification, Bayesian deep learning, data-driven augmentation, contextual ML	Modern synoptic sky surveys have proven transformative for our understanding of astrophysical transients and their place in the wider Universe, only made possible by high-performance machine learning classification to efficiently filter astrophysical sources from artifacts in the vast quantities of data these projects generate. With upcoming step changes in survey capability (e.g. VRO) further increasing this data rate, it is clear continued innovation is required to continue to efficiently leverage this discovery stream. In this talk I will present recent progress (Killestein et al., 2021) on the real-bogus classification problem, applied to the incoming datastream of the Gravitational-wave Optical Transient Observer (GOTO) transient survey. We introduce a fully automated data generation procedure leveraging astronomical catalogs that minimises required human labelling, and a novel data-driven augmentation scheme to markedly increase the recovery of faint/nuclear extragalactic transients that form the principal science targets of surveys like GOTO. Another key step forward is the application of Bayesian convolutional neural networks to this difference image source classification problem for the first time. This direct quantification of model uncertainty through score posteriors provides a richer decision space than one-dimensional classifier scores, enabling principled active learning strategies to be employed, and showing emerging promise in the context of more complex classification tasks. I will also motivate a new approach of context-aware hierarchical meta-classification currently under development -- with the aim of further automating time-consuming transient stream vetting, providing rich classification, and maximising science returns from current and future transient surveys.

Ingo	Waldmann	Deep learning in Exoplanet Characterisation	Extrasolar Planets	Explainable AI, Supervised and unsupervised learning	The use of machine and deep learning is prevalent in many fields of science and industry and is now becoming more widespread in extrasolar planet and solar system sciences. Deep learning holds many potential advantages when it comes to modelling highly non-linear data, as well as speed improvements when compared to traditional analysis and modelling techniques. In this seminar, I will focus on two aspects of characterising extrasolar planets: the data analysis and the atmospheric inverse modelling. In the first part of my talk, I will discuss how we can use machine learning and deep autoregressive models to de-trend exoplanet time-series observations from instrumental and astrophysical noise. In the second part, I will discuss our recent work on developing Explainable AI approaches for exoplanet atmospheric modelling. By making these ‚Äòblack box‚Äô models more interpretable, we begin to understand how different neural net architectures learn to model atmospheric spectra. This allows us to¬† derive more robust prediction uncertainties as well as map information content as function of wavelength. As data and model complexities are bound to increase dramatically with the advent of JWST and ELT measurements, robust and interpretable deep learning models will become valuable tools in our data analysis repertoire. ¬†¬†
Edward	Elliott	Emulation of semi-analytic models of galaxy formation	Galaxy Formation	Deep learning/Bayesian deep learning	I present methods for efficient emulation of parameterised semi-analytic models of galaxy formation using a combination of deep learning and space-filling sampling. I show that deep learning algorithms are able to accurately reproduce the summary statistics of the full model from a small number of training examples, allowing us to explore the model‚Äôs full parameter space at low computational cost. By performing a sensitivity analysis, I show that we can quantify the relative importance of parameters when fitting to different observational datasets. Further, I discuss Bayesian neural networks, a class of deep learning algorithms which are able to incorporate measures of uncertainty into their predictions, and show how this allows us to rapidly and robustly calibrate the model parameters to a set of observational datasets.
Alan	Heavens	The Universe is a mess: how should we analyse it?	Cosmology	Simulation-based inference; ML of probability distributions	The non-Gaussian nature of the present Universe presents major challenges for data analysis. In this talk, I compare three generic methods for doing such an analysis, using the lognormal model, a proxy for the present-day fields that shares many characteristics of the gravitationally-evolved field, but which has some nice analytic properties. I compare a) traditional 2-point correlation function analysis; b) ML, simulation-based inference (also known as likelihood-free inference, or LFI; c) a full field-based likelihood, also sometimes referred to as a Bayesian Hierarchical Model. We find that c) outperforms the others considerably, even for nearly-gaussian fileds. I also discuss why it is that c > b > a.
Michele	Bianco	Deep Learning Approach Identification of HII regions during Reionization in 21-cm Observations	Cosmic Reionization	U-Net, Convolutional Neural Network, Deep learning, Image processing	The upcoming Square Kilometre Array (SKA-Low) will map the distribution of neutral hydrogen during reionization, and produce a tremendous amount of 3D tomographic data. These images cubes will be subject to instrumental limitations, such as noise and limited resolution. Here we present SegU-Net, a stable and reliable method for identification of neutral and ionized regions in these images. SegU-Net is a U-Net architecture based convolutional neural network (CNN) for image segmentation. It is capable of segmenting our image data into meaningful features (ionized and neutral regions) with greater accuracy compared to previous methods. We can estimate the true ionization history from our mock observation of SKA with an observation time of1000 h with more than 87 per cent accuracy. We also show that SegU-Net can be used to recover various topological summary statistics, such as size distributions and Betti numbers, with a relative difference of only a few per cent. These summary statistics characterise the non-Gaussian nature of the reionization process
Paula	Soares	Gaussian Process Regression: An Application in Radio Cosmology	Radio cosmology	Gaussian Process Regression	Neutral hydrogen (HI) intensity mapping (IM) is a novel technique able to probe the 3D large-scale structure of the Universe over very large volumes. By treating HI as a diffuse background, we are able to use it as a biased tracer for the underlying dark matter distribution. It is possible to then calculate statistics such as the HI power spectrum. However, in order to achieve high precision and accuracy using HI IM, instrumental and systematic effects must be properly accounted for. In particular, astrophysical foregrounds dominate over the signal by several orders of magnitude, and need be adequately removed. I look at the performance of Gaussian Process Regression (GPR) as a foreground removal technique. This non-parametric technique is able to statistically separate the spectrally smooth foregrounds from the HI cosmological signal. While this technique has been applied to interferometric HI IM data from the Epoch of Reionization, I apply it for the first time to simulations of single dish, large scale structure HI IM studies. Specifically, I apply GPR as a foreground removal technique to MeerKAT-like simulations, which include instrumental and systematic effects. I conclude by comparing the performance of GPR in recovering the HI cosmological signal to other known foreground removal methods, such as Principle Component Analysis.
Pablo	Lemos	Rediscovering Newton's gravity and Solar System properties using deep learning and inductive biases	Gravitation	Deep learning, symbolic regression	We present an approach for using machine learning to automatically discover a physical law and associated properties of the system from real observations. We trained a neural network-based architecture, whose structure corresponds to classical mechanics, to simulate the dynamics of our Solar System from 30 years of observed trajectory data. We then used symbolic regression to extract a symbolic formula for the force law, which our results show matches Newtonian gravity. We find that by scaling the model's predicted acceleration by a trainable scalar variable, we could infer bodies' (relative) masses despite that they were not observable in the data itself. Though ``Newtonian'' gravity has of course been known since Newton, our approach did not require knowledge of this physical law, and so our results serve as a proof of principle that our method can extract unknown laws from observed data. This work takes a step towards using modern machine learning tools beyond data processing and analysis, but automated scientific theory formation and development.