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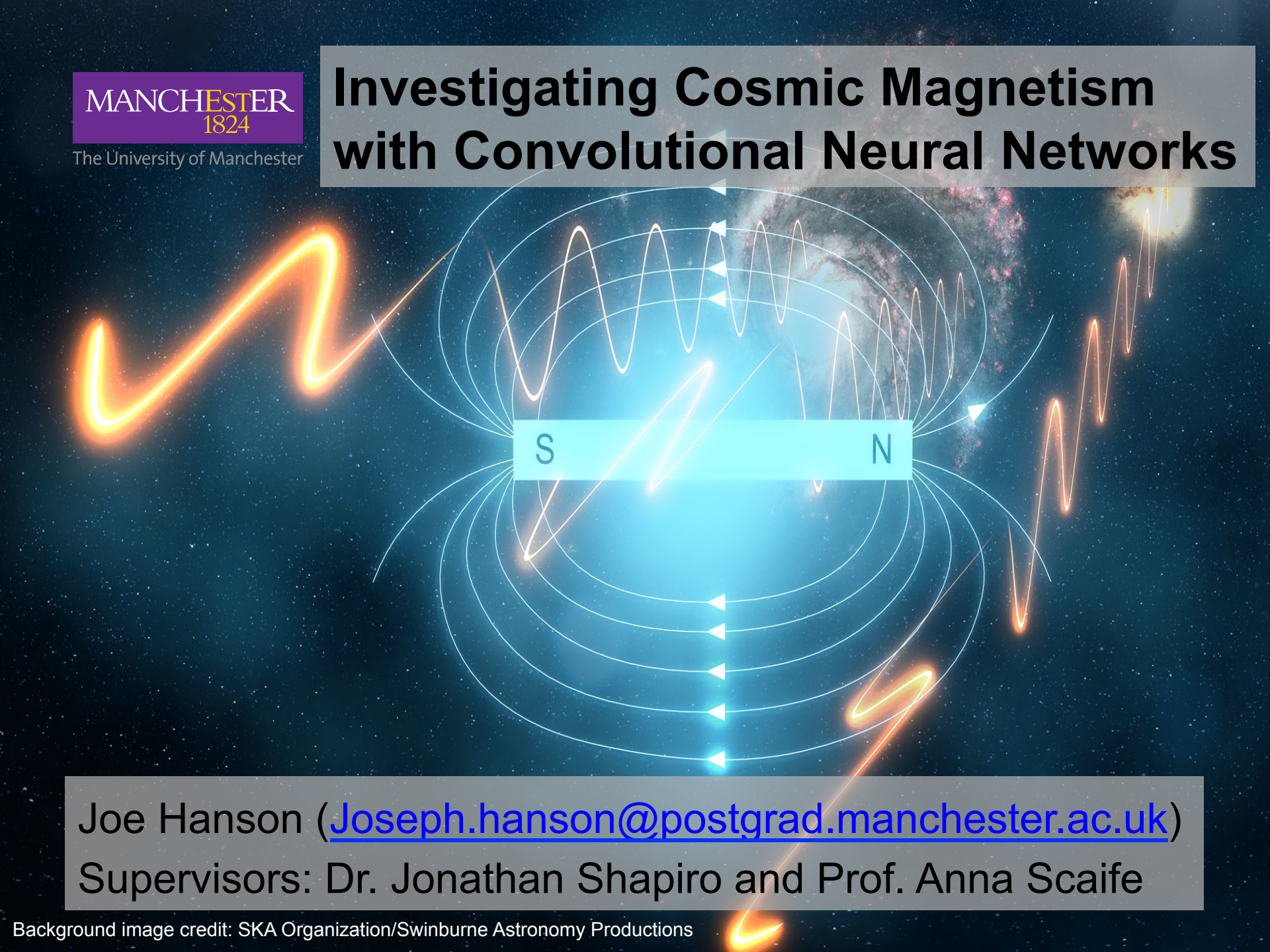
Investigating Cosmic Magnetism with Convolutional Neural Networks



Joe Hanson (Joseph.hanson@postgrad.manchester.ac.uk)
Supervisors: Dr. Jonathan Shapiro and Prof. Anna Scaife

Background image credit: SKA Organization/Swinburne Astronomy Productions

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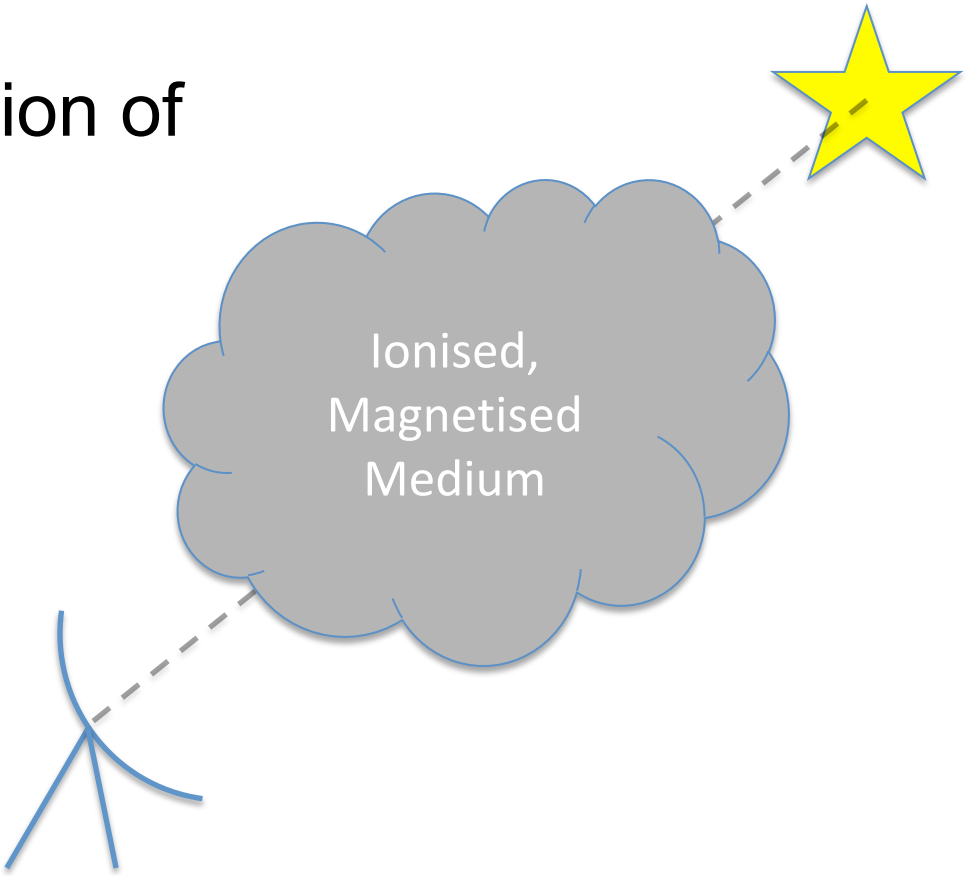
Magnetism Background

- "The Origin and Evolution of Magnetic Fields" SKA Key Science Project

- **Faraday Effect**: Magnetic fields cause a rotation in the plane of polarisation



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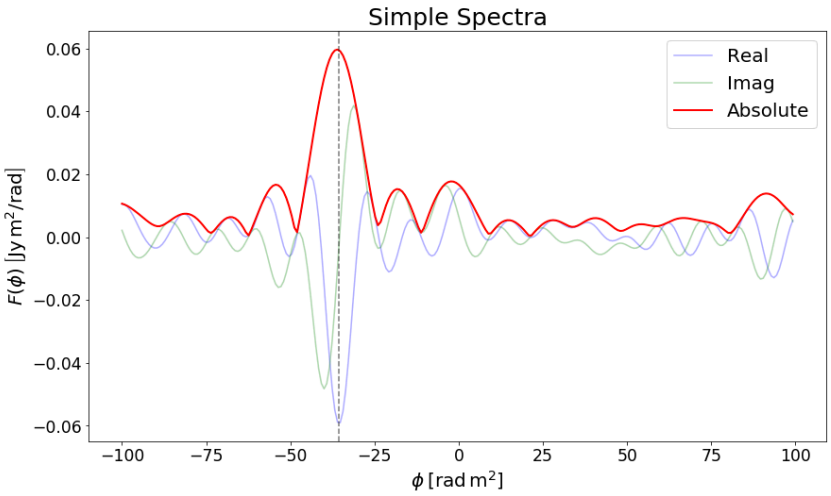
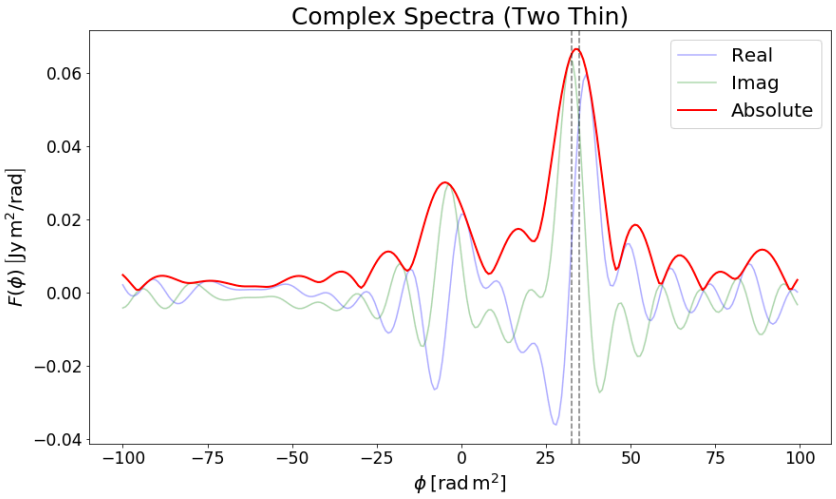
Machine Learning Motivation

- Classification problem with Faraday Spectra.
- Unprecedented **quality** and **quantity** of data.

➔ Machine Learning!





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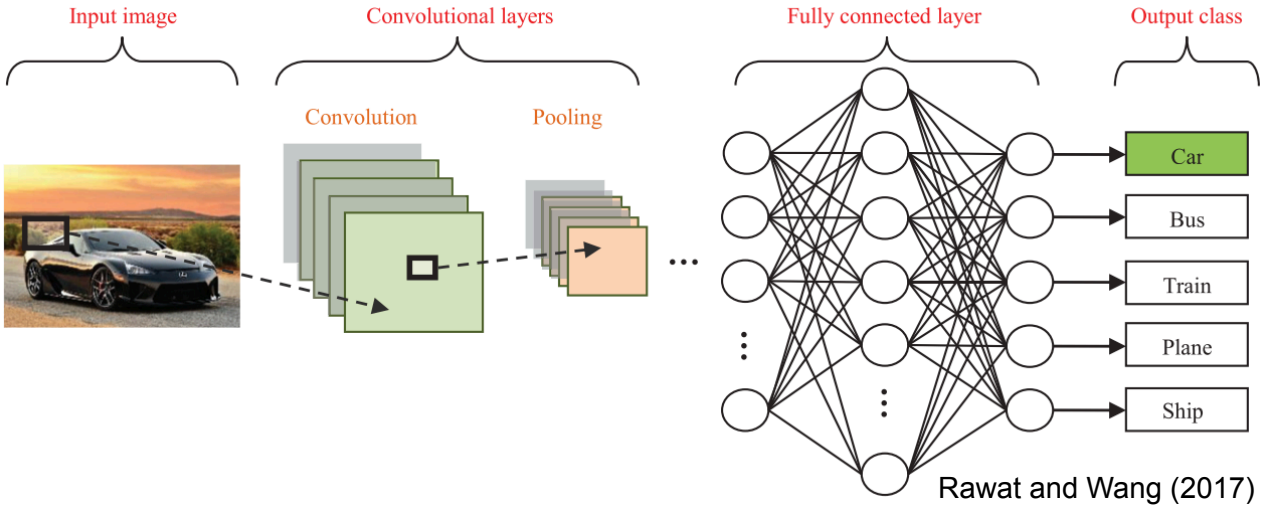
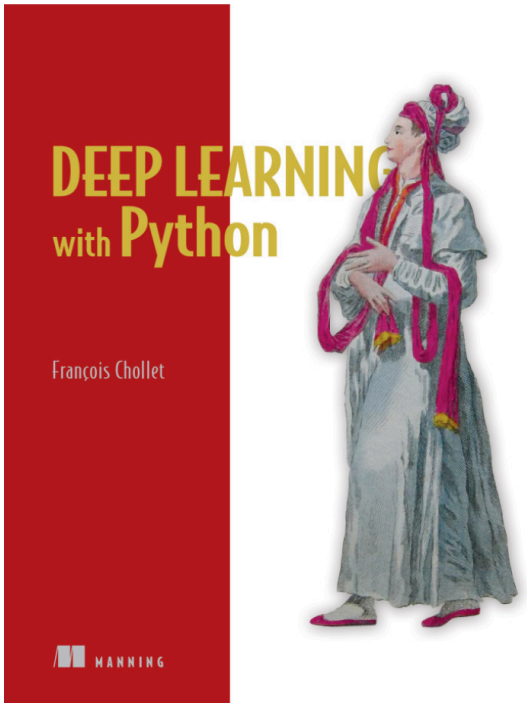


Rawat and Wang (2017)

Why CNN's?

- CNN's have achieved exceptional performance for image recognition.
- Classifying Faraday spectra is a similar task.
- High performing in theory, and highest-performing experimentally (for me, so far)



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Brown et al. (2017)

Past Work

- Classification between binary, balanced ASKAP-simulated dataset of simple (one thin) and complex (two thin) cases.

94.9% accurate

Table 2. Confusion Matrix: Before Cutoffs

Predicted – >	Simple	Complex
True Simple	48,318	1481
True Complex	3,618	46,583

99.4% accurate

Table 3. Confusion Matrix: After Cutoffs

Predicted – >	Simple	Complex
True Simple	29,281	69
True Complex	247	25,337

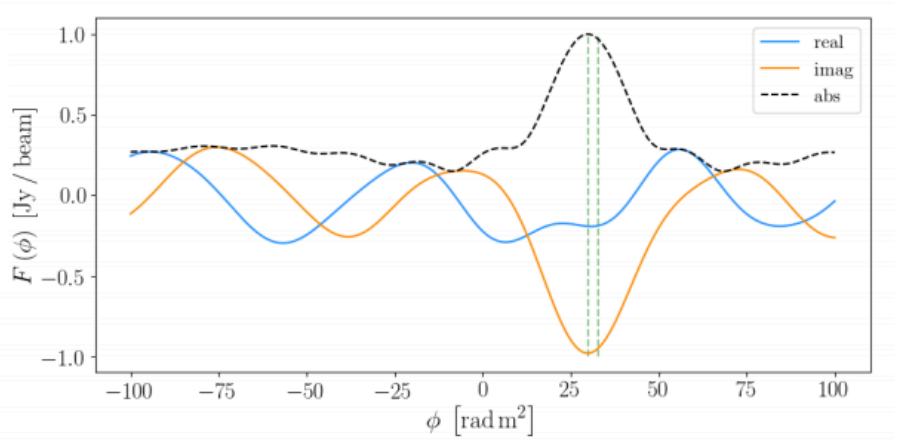

Figure 7. Top: Faraday spectrum of a complex source misidentified as simple by the classifier. The two Faraday depths are labeled with vertical green dashed lines.

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My Research with CNN's

- Imbalanced, multi-class simulated MeerKAT dataset.
- Currently working with simulated data, awaiting real data.

Random Forest

Actual Class \ Predicted Class	Unpolarised	Simple	Complex
Unpolarised	2243 (100%)	0 (0.0%)	0 (0.0%)
Simple	85 (65.9%)	42 (32.6%)	2 (1.6%)
Complex	73 (57.0%)	2 (1.6%)	53 (41.4%)

Neural Network (non-CNN)

	Unpolarised	Simple	Complex
Unpolarised	2133 (95.1%)	61 (2.7%)	49 (2.2%)
Simple	12 (9.3%)	77 (59.7%)	40 (31.0%)
Complex	22 (17.2%)	44 (34.4%)	62 (48.4%)

CNN

	Unpolarised	Simple	Complex
Unpolarised	2230 (99.4%)	4 (0.2%)	9 (0.4%)
Simple	12 (9.3%)	112 (86.8%)	5 (3.9%)
Complex	10 (7.8%)	21 (16.4%)	97 (75.8%)

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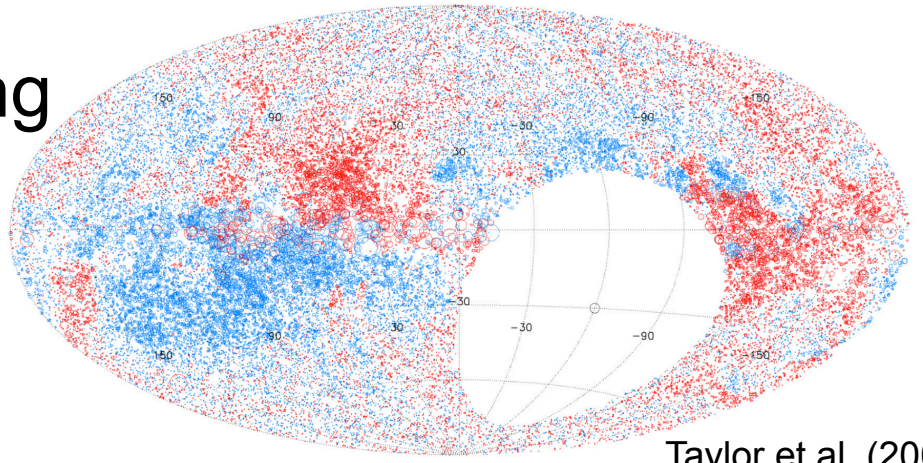
Undersample the majority

Oversample the minority

Combinations or Ensembles

Research Problems

- Class imbalance
  - Cost-sensitive learning
  - Resampling



Taylor et al. (2009)

- Transitioning from simulated to real data
  - Semi-supervised learning?
  - Transfer learning?

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Image credit: SKA South Africa

Summary

- The Faraday Effect help us to observe distant magnetic fields.
- New radio telescopes provides big data which both enables and demands new methods.
- Results on real data should be interesting!
- CNN's are particularly useful for many tasks related to image classification, and classifying Faraday spectra looks to be among them.

Thanks for listening! ☺