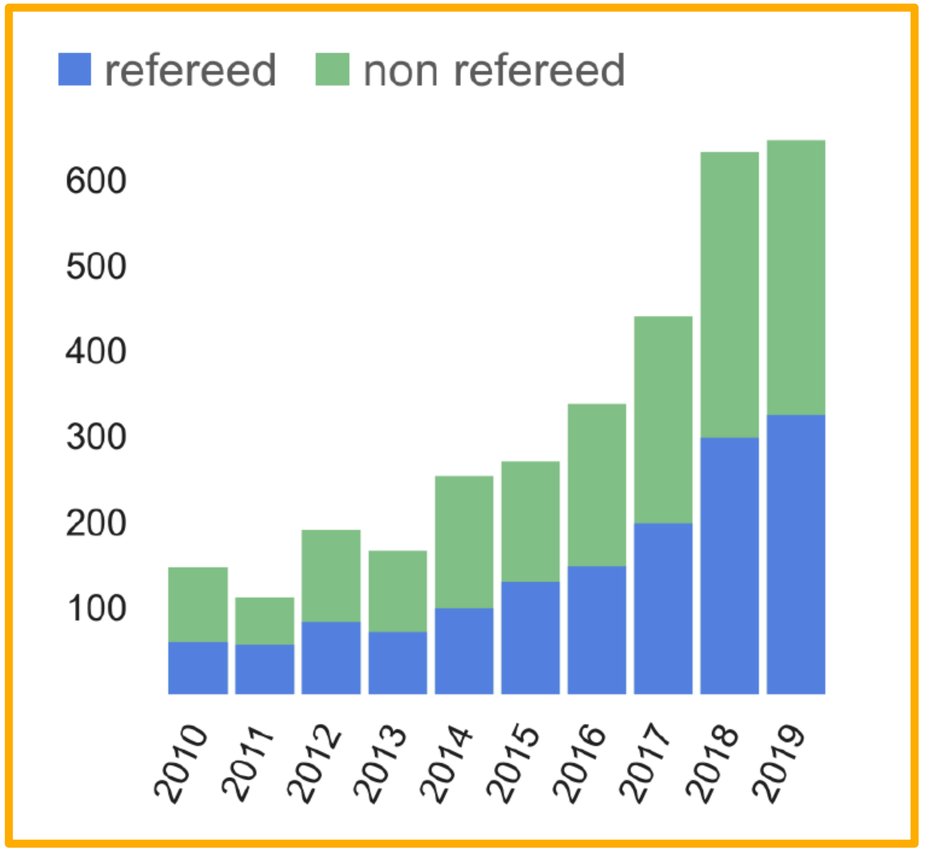
AI for Astronomy in the SKA Era

Anna Scaife
Jodrell Bank Centre for Astrophysics

Swiss SKA Days 2021

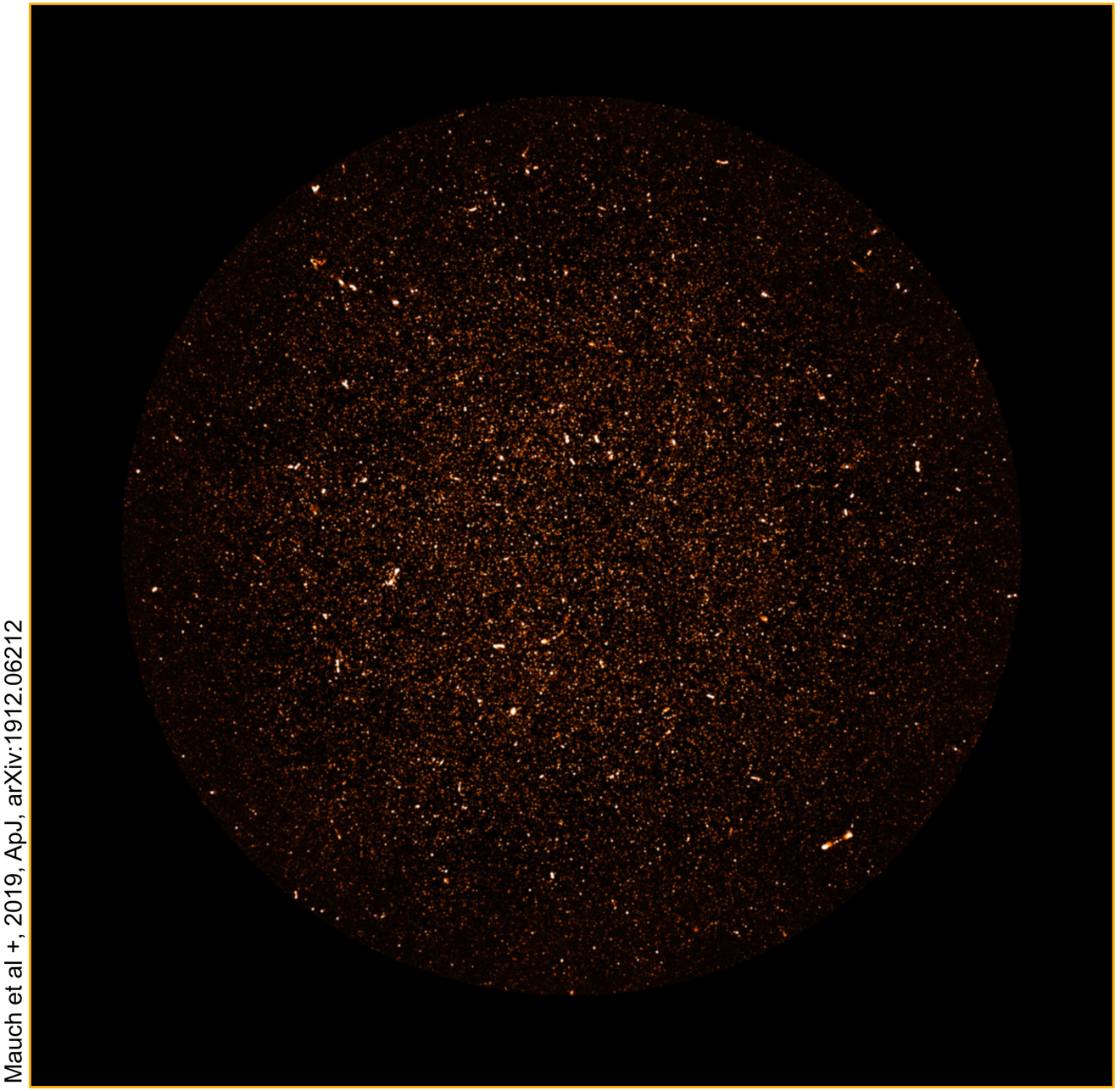
What are the factors that motivate the use of AI for SKA?



Astronomy papers that include machine learning methods in the abstract or title since 2010, from the Astrophysics Data System (ADS) **Venn et al 2019**

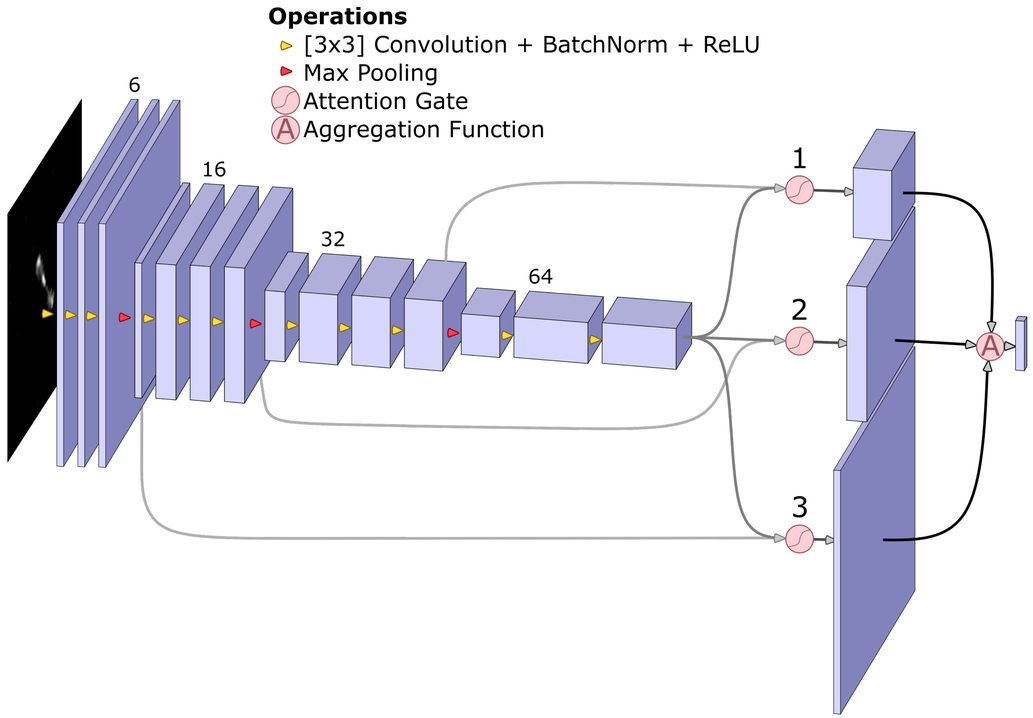
- Large astrophysical populations;
- High data rates;
- Complex relational dependencies;
- Computational barriers to participation.

- Scientific (analysis);
- Scientific (operational);
- Operational (e.g. predictive maintenance, scheduling).



Mauch et al +, 2019, ApJ, arXiv:1912.06212

- Much of modern astrophysics is driven by population analyses;
- Populations need to be extracted from observational data;
- New discoveries need to be separated from known populations.



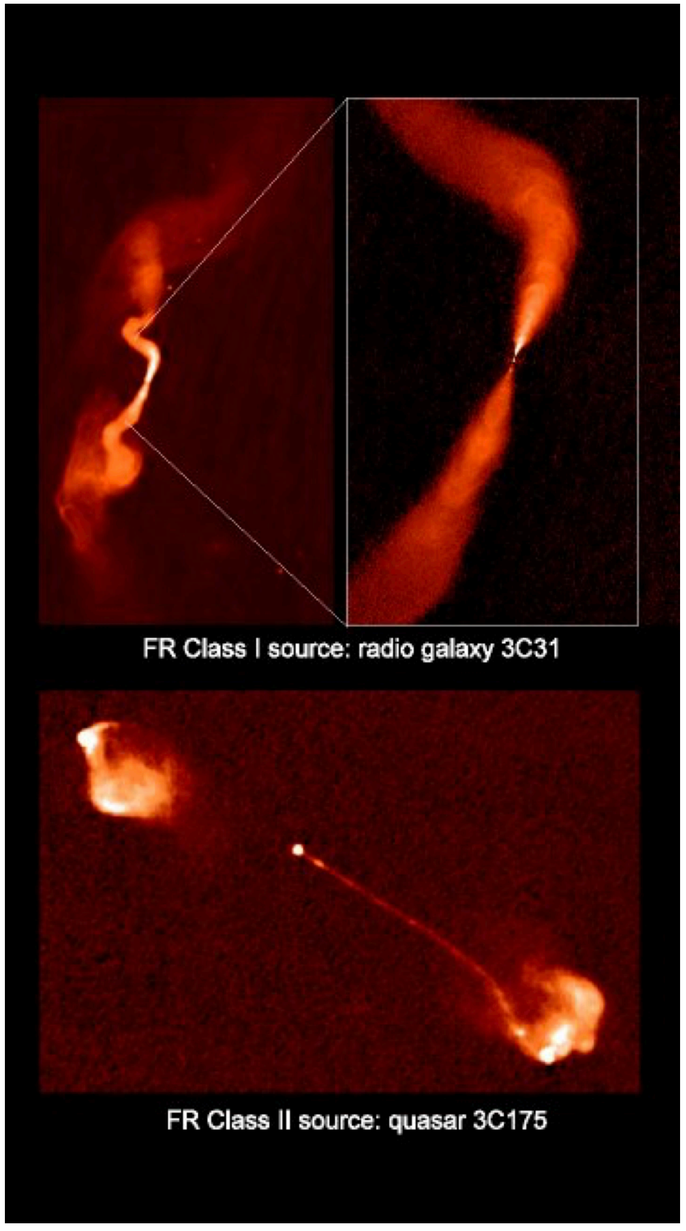
Bowles, AMS +, 2021, MNRAS, arXiv:2012.01248

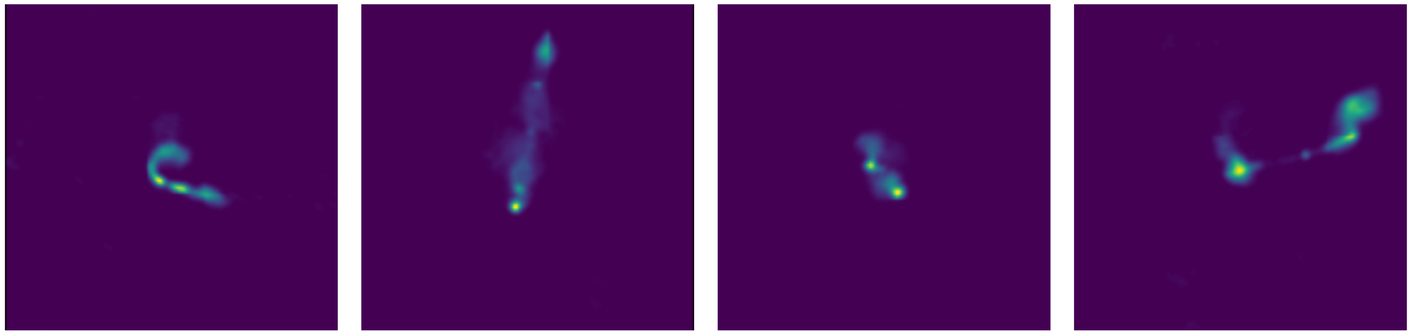
What are the issues that face the systematic use of AI for SKA?

- A paucity of labelled data for training - paradoxically, although we have too much data, we don't have enough;

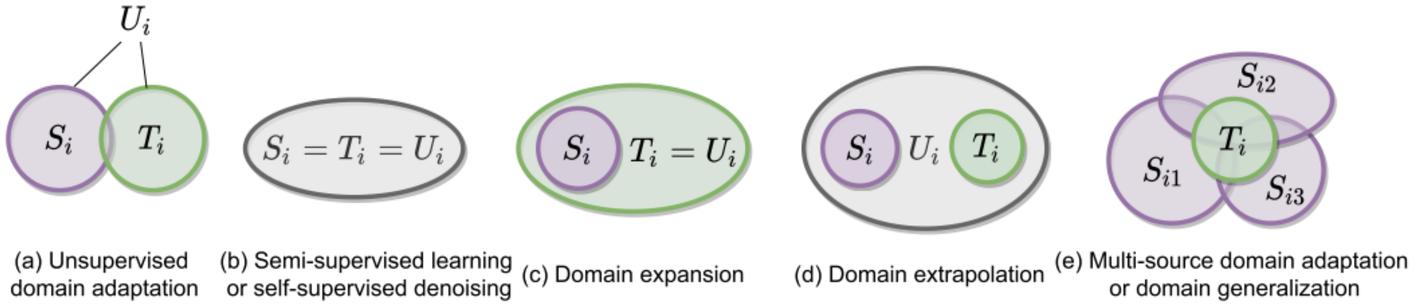
- A clear understanding of the effect of biases introduced due to observational and intrinsic astrophysical selection effects in the training data;

- The quantitative statistical representation of outcomes from decisive AI applications that can be used in scientific analysis.





- Large archival databases but only small labelled data sets;
- Significant and variable class imbalances;
- Need carefully calibrated uncertainties on model outputs;
- Need for biases in model outputs to be quantitatively estimated.



(a) Unsupervised domain adaptation | (b) Semi-supervised learning or self-supervised denoising | (c) Domain expansion | (d) Domain extrapolation | (e) Multi-source domain adaptation or domain generalization

Cai+, 2021, arXiv:2102.11203

Standard CNN

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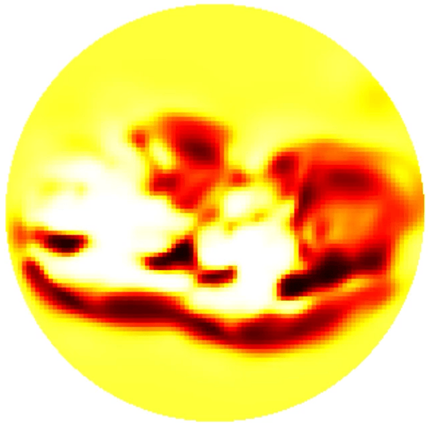
feature map



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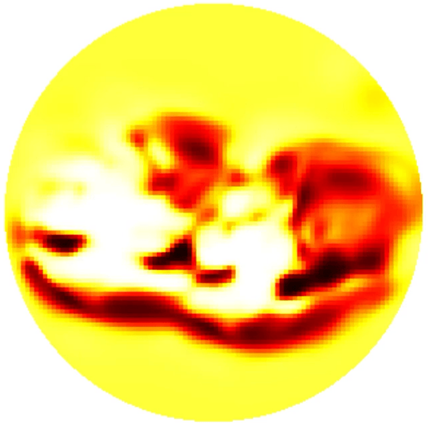

Group-equivariant CNN

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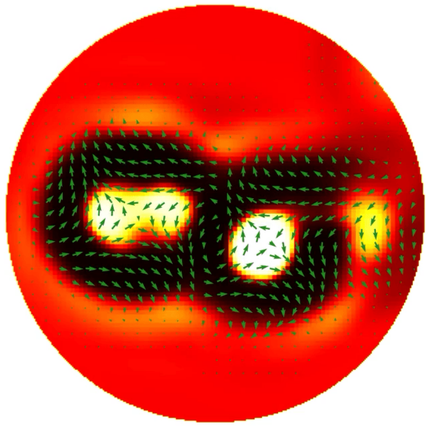
feature fields



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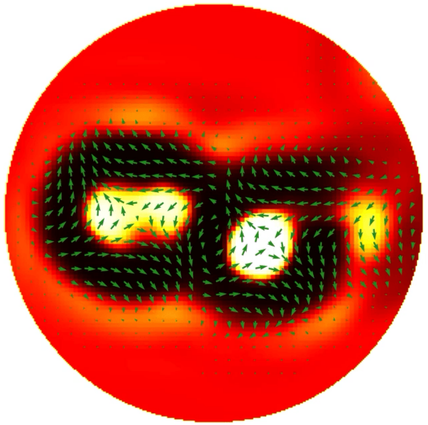

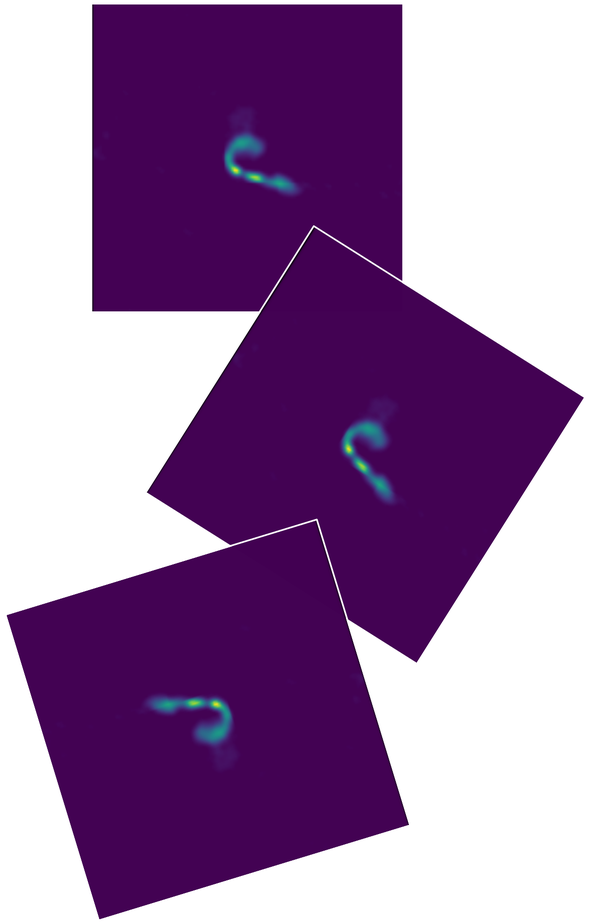

AMS & Porter, 2021, MNRAS, arXiv:2102.08252

Standard CNN

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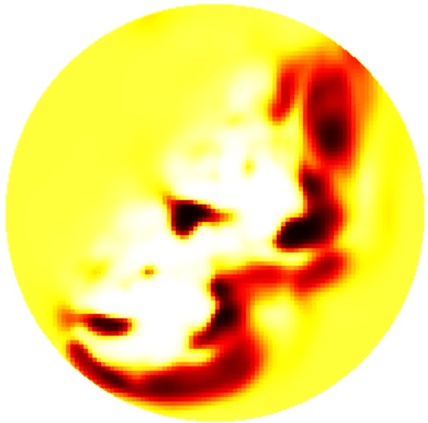

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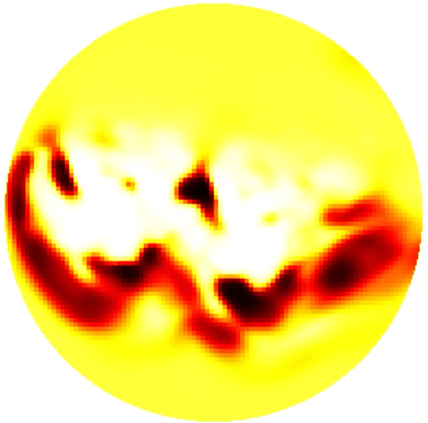

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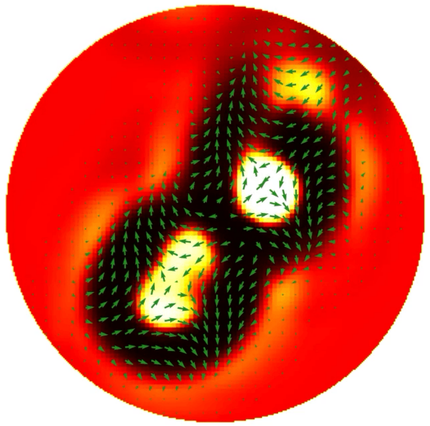

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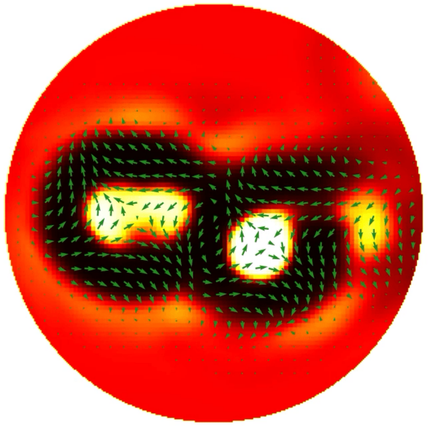

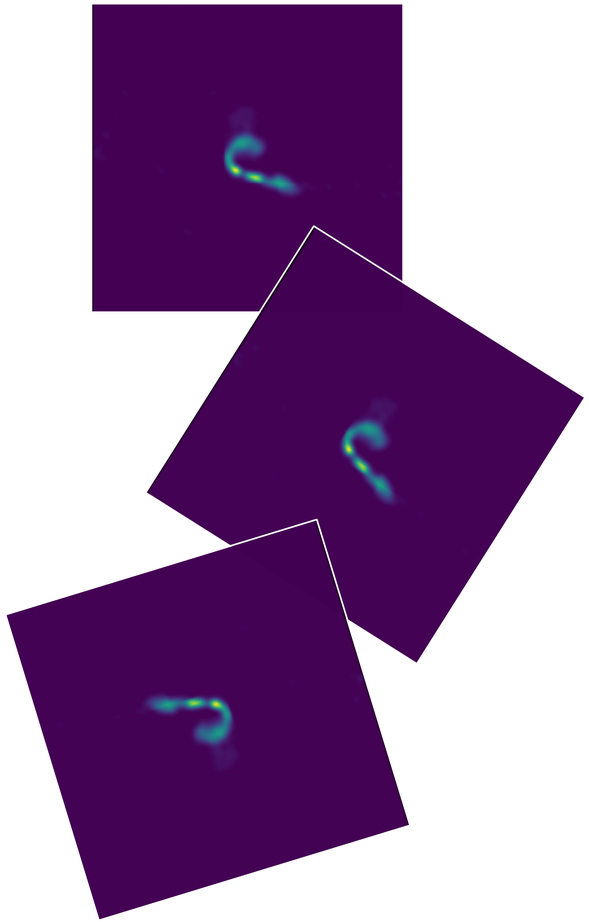

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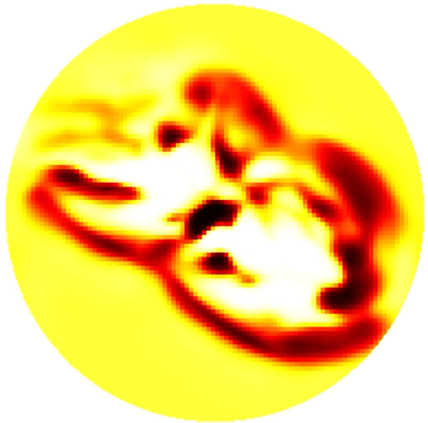

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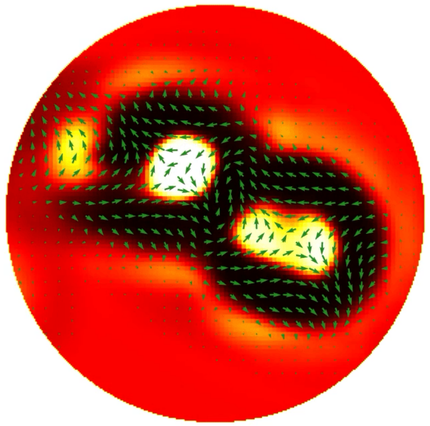

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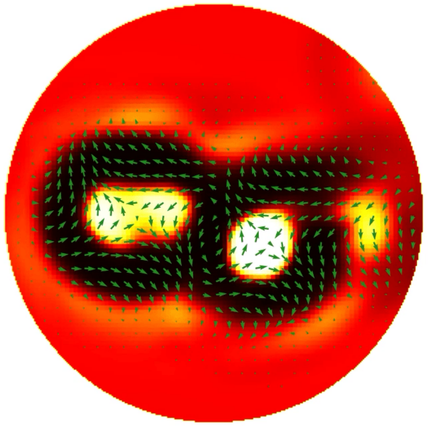

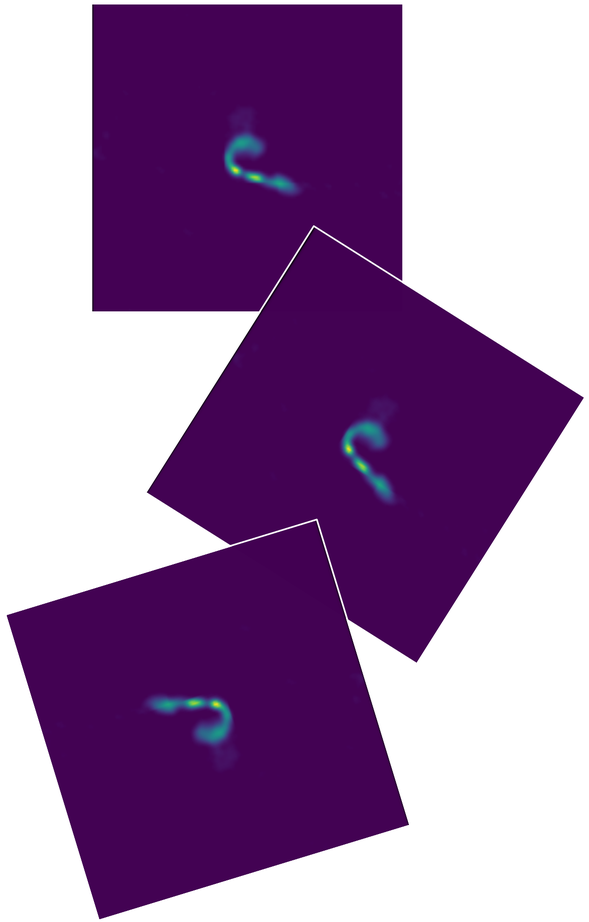

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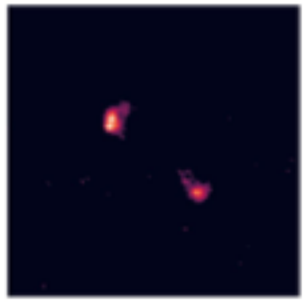
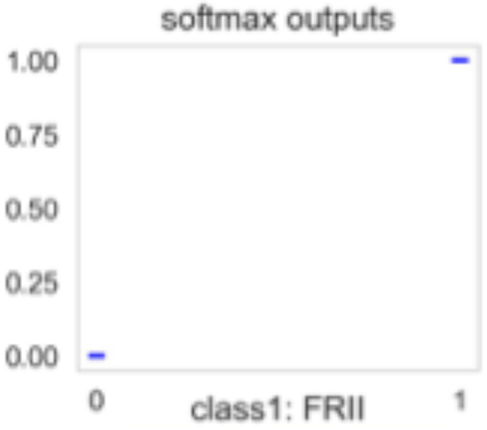
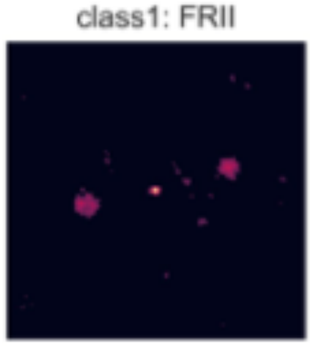
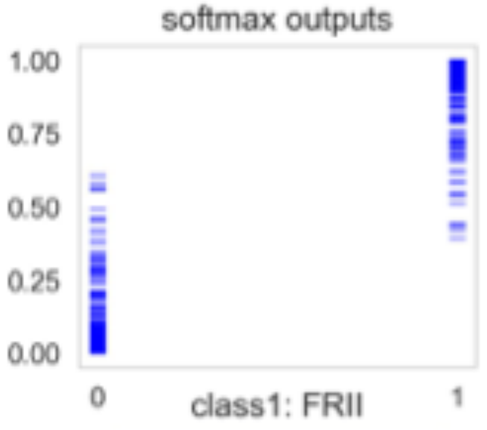
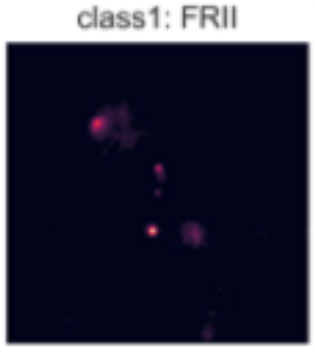
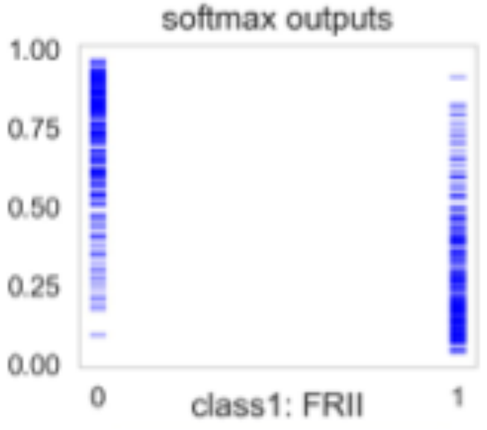








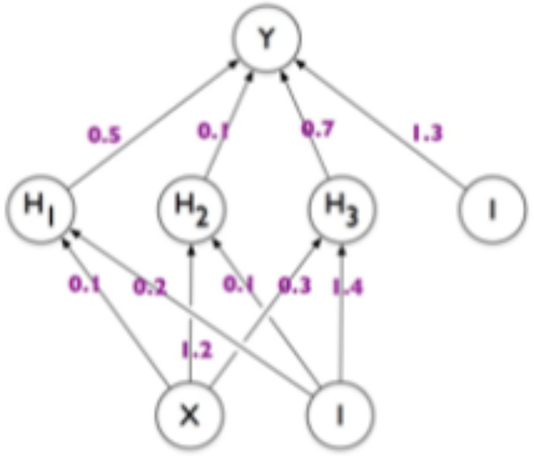


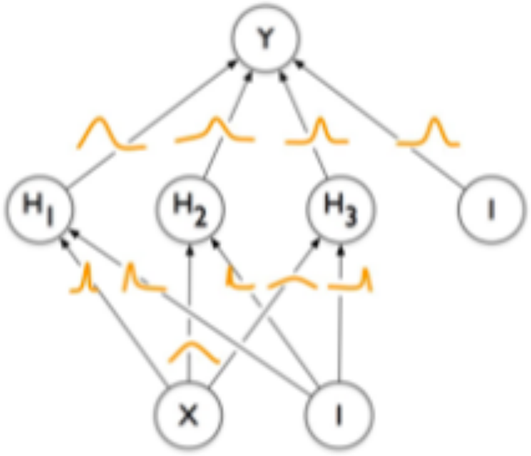


Mohan, AMS +,in prep.

Bayesian Neural Networks

- Allow us to recover posterior probability distributions;
- Provide a measure of how uncertain the *model* is in its prediction.
- Allow us to rank the importance of different weights within the model.

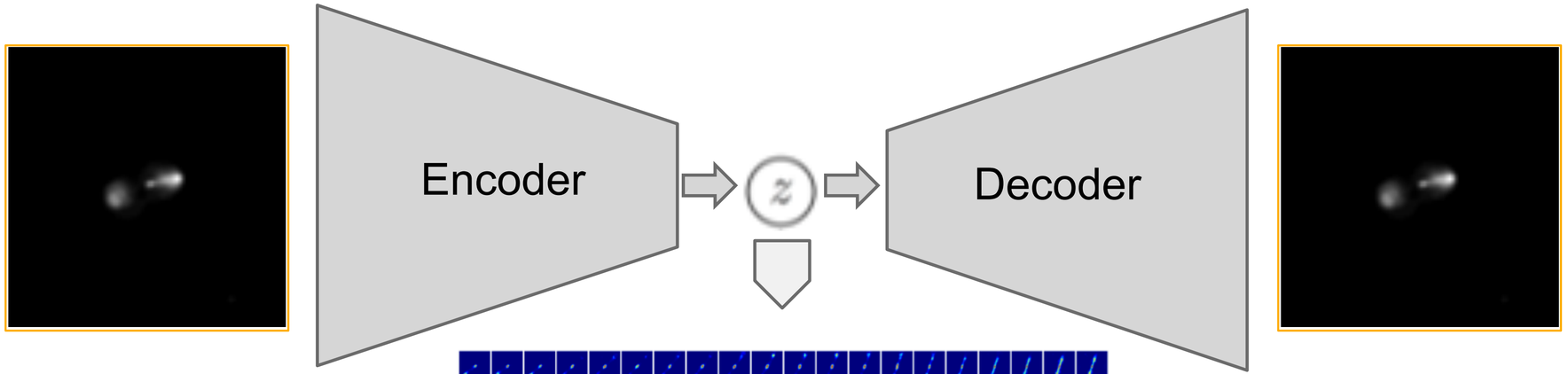


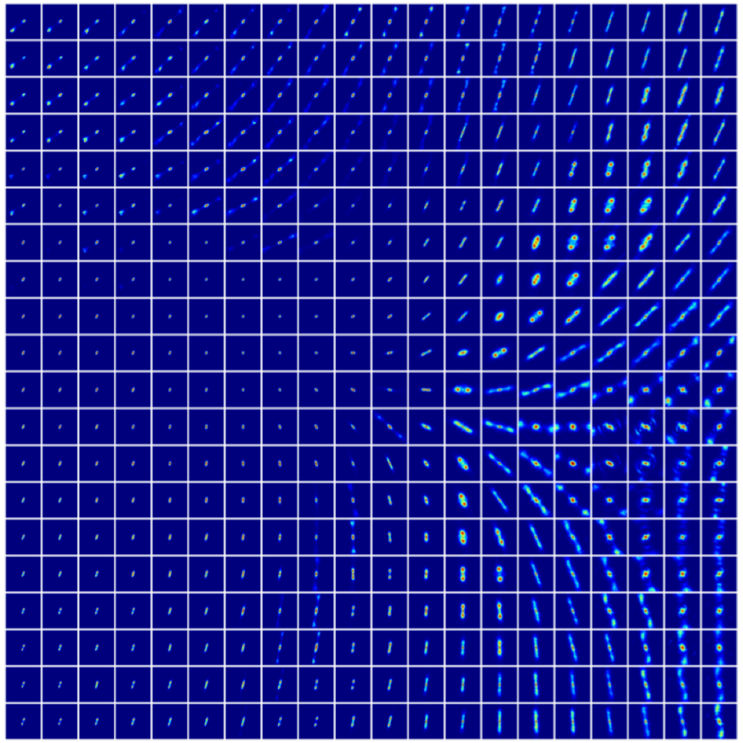


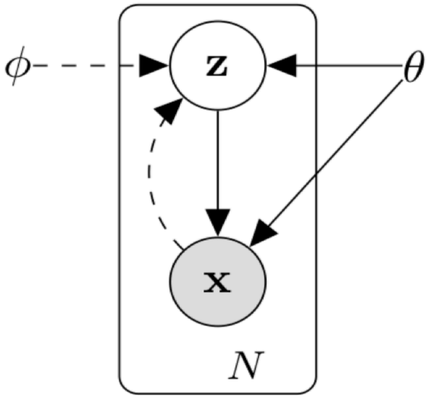
Blundell et al. (2015)

$$ELBO = \mathbb{E}[log\, p(D|w)] - KL(p(w|D)||p(w))$$

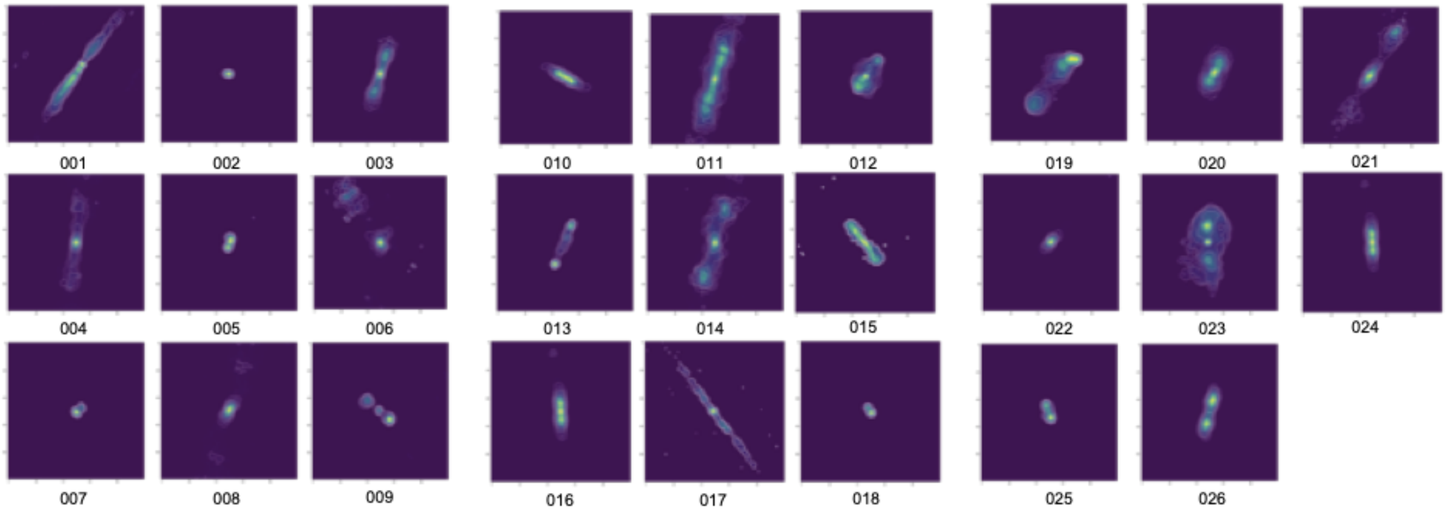
Generative AI for SKA Data Challenges





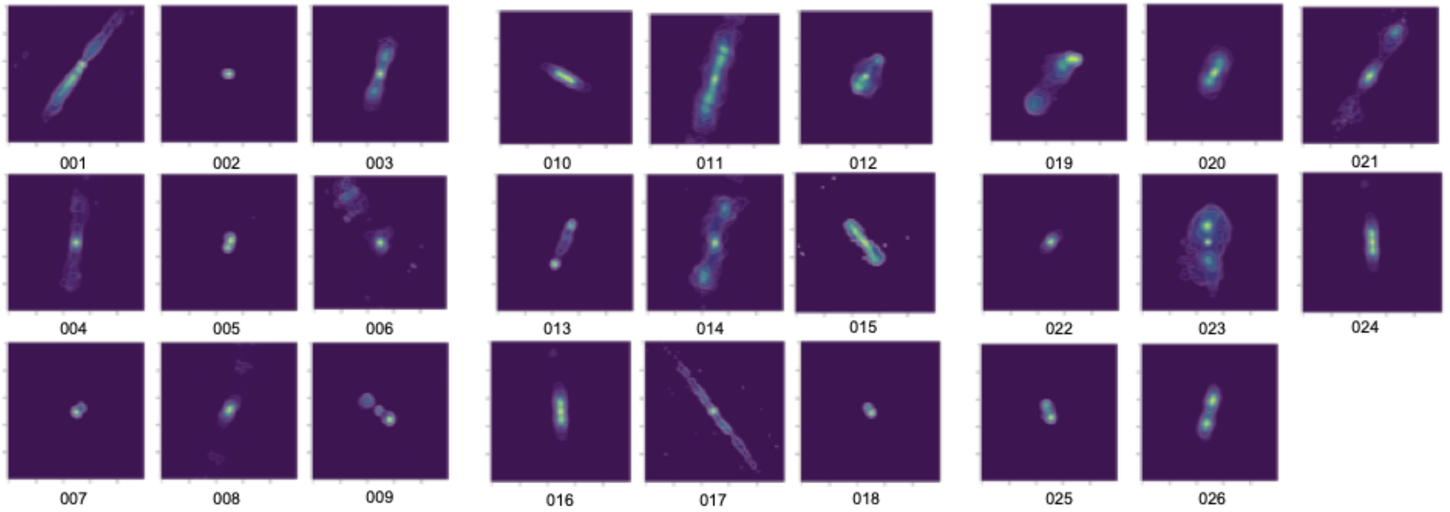


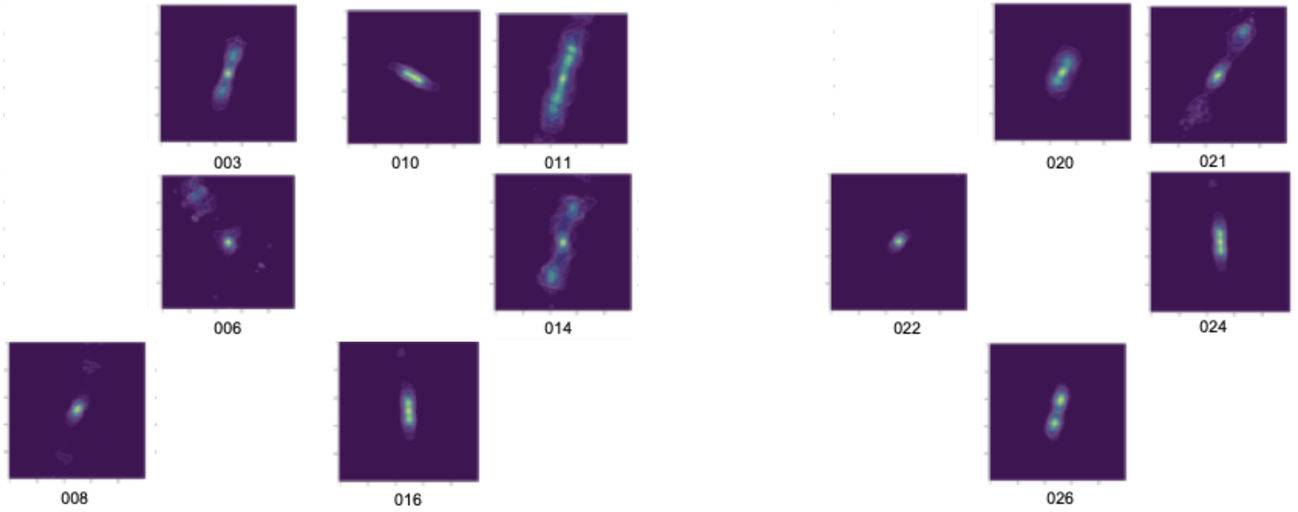
Bastien, AMS +, 2021, MNRAS, arXiv:2102.01007



Real or Fake?

Bastien, AMS +, 2021, MNRAS, arXiv:2102.01007





Real or Fake?

Bastien, AMS +, 2021, MNRAS, arXiv:2102.01007

Conclusions

- The digital revolution has vastly increased the sensitivity and utility of radio telescopes;
- New radio telescopes are big data machines;
- AI is essential for extracting scientific impact in a timely fashion –
- However, quantitative estimates of uncertainty and bias on AI outputs are essential for scientific use;
- We must not "automate out" the potential for DISCOVERY.

SKAO

MANCHESTER 1824
The University of Manchester
Jodrell Bank Observatory

The Alan Turing Institute