Machine Learning Applications for Images in Astronomy

(Explained in the context of radio astronomy)

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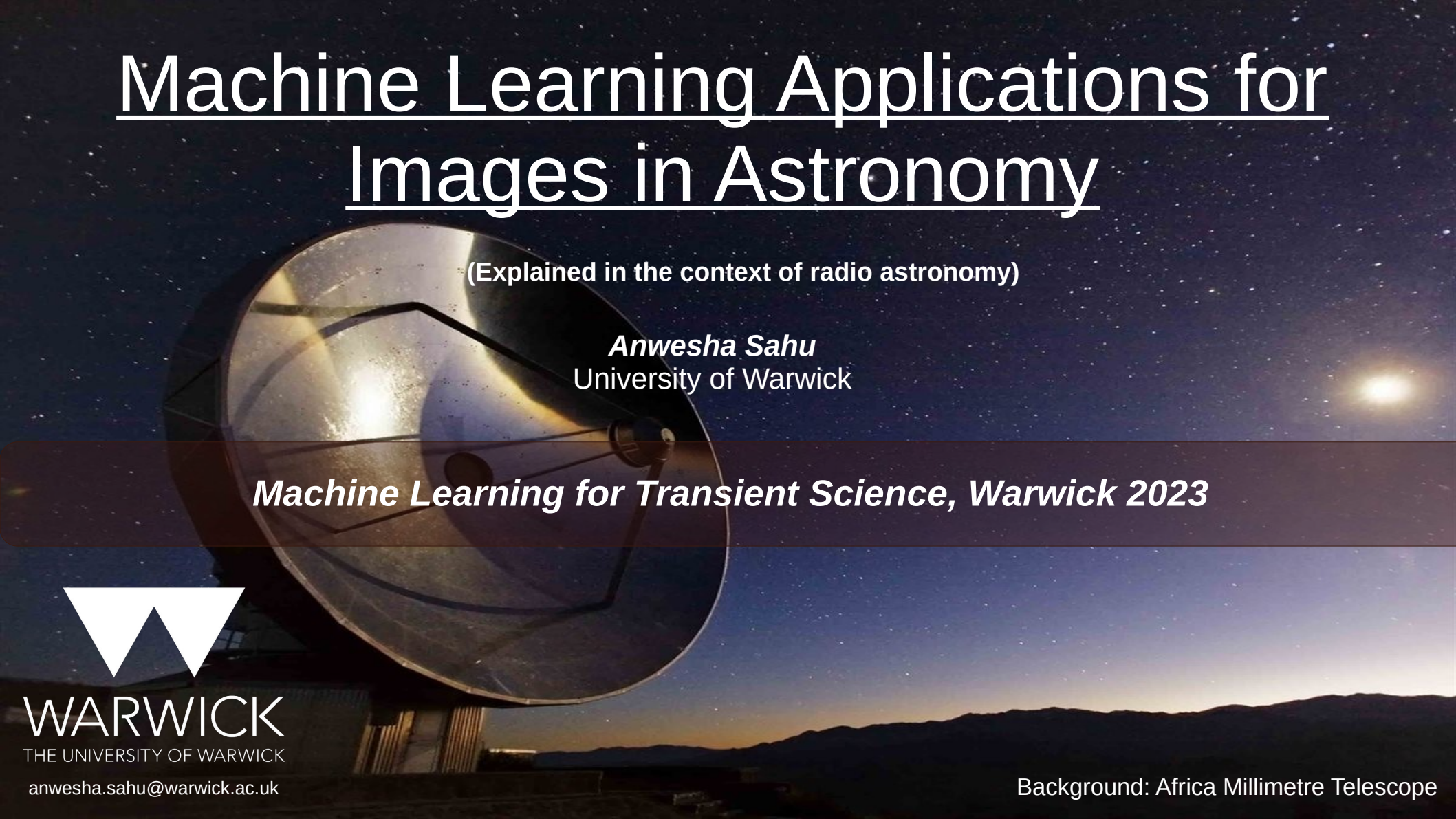
Machine Learning for Transient Science, Warwick 2023



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Background: Africa Millimetre Telescope

Outline

1. ML terminology
2. Radio astronomy terminology
3. An application: My MSci dissertation summary
4. Prospects with transients
5. Summary and Questions

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ML terminology

Computer vision

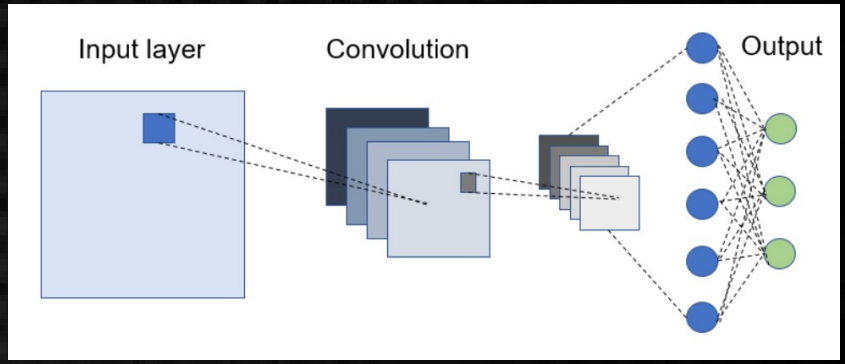
Neural Network + layers

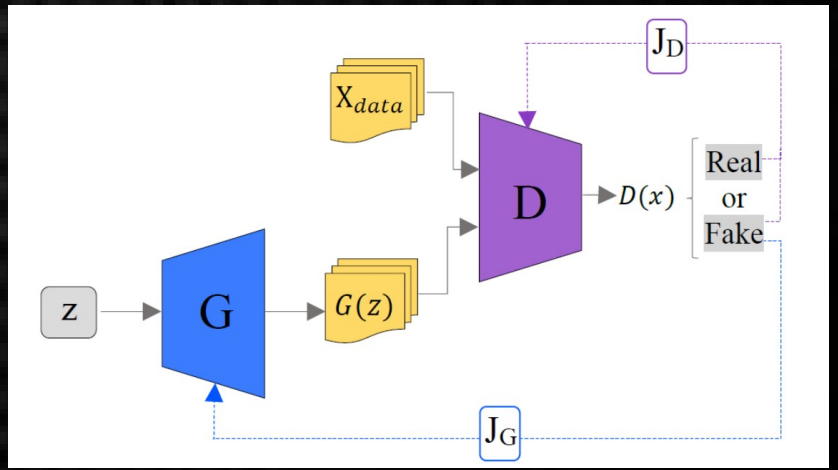
Activation Functions

Augmentation

Multi-class classification algorithm

GANs: discriminator vs. generator





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Radio Astronomy 101

Images: VLA NRAO, MeerKAT

Radio interferometry

Baseline

VLA FIRST Survey

MeerKAT

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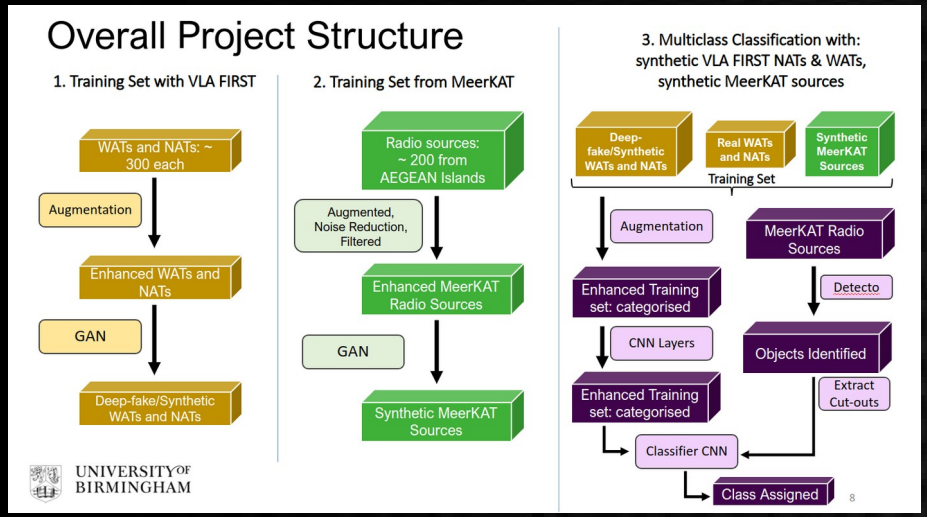
An Application



Will be enlarged next slide :)

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Anwesha Sahu
MSci Physics with Particle Physics and Cosmology

MSci Project Report

Machine Learning Applications in Radio Astronomy

5th May 2023

Abstract

The applications of convolutional neural networks and computer vision for classification, object identification and big data problems in radio astronomy is studied in this project report. This project used images from the MeerKAT Galactic Plane Survey and VLA FIRST Survey for training and generating synthetic data, with the goal of identifying and classifying radio objects of interest in the MeerKAT Galactic Plane Survey. Using 8028 augmented images for training a generative adversarial network to produce synthetic images for use in a multiclass classification model trained with 6248 images, a validation accuracy of 80.7% for the multiclass classification model was obtained. The methods studied can be applied to automate object identification and classification as upcoming large scale astronomy projects currently face the key challenge of processing copious amounts of data.

An Application – but first, pictures because I'm an astronomer who loves pretty pictures

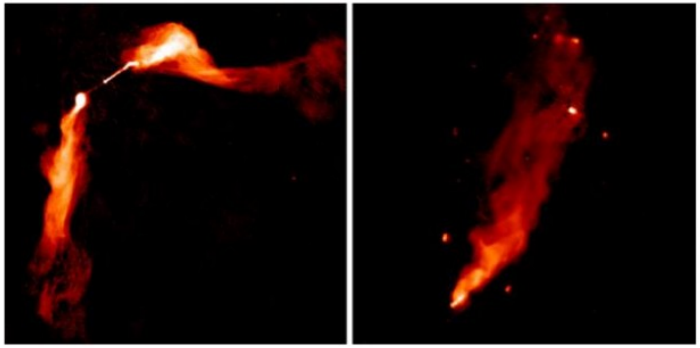


Figure 8a (*left*): WAT source 3C465. Note the wide angle between the tails [18].
Figure 8b (*right*): NAT source NGC6109. This source is also a HT object [18].

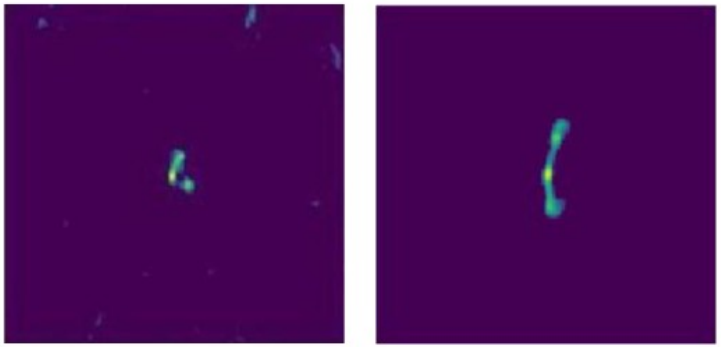


Figure 11a (*left*): NAT from VLA FIRST. Note the acute opening angle [27].
Figure 11b *(right)*: WAT from VLA FIRST. Note the obtuse opening angle [27].

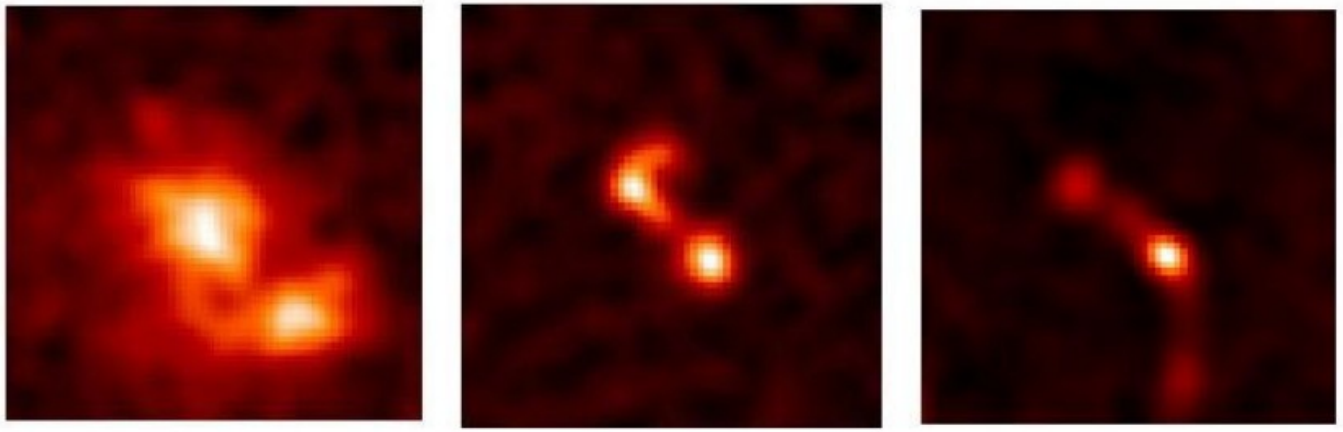
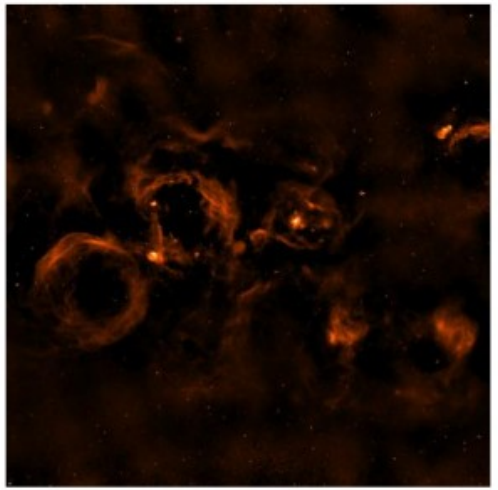


Figure 10: Examples of objects in MeerKAT GPS cut-outs.



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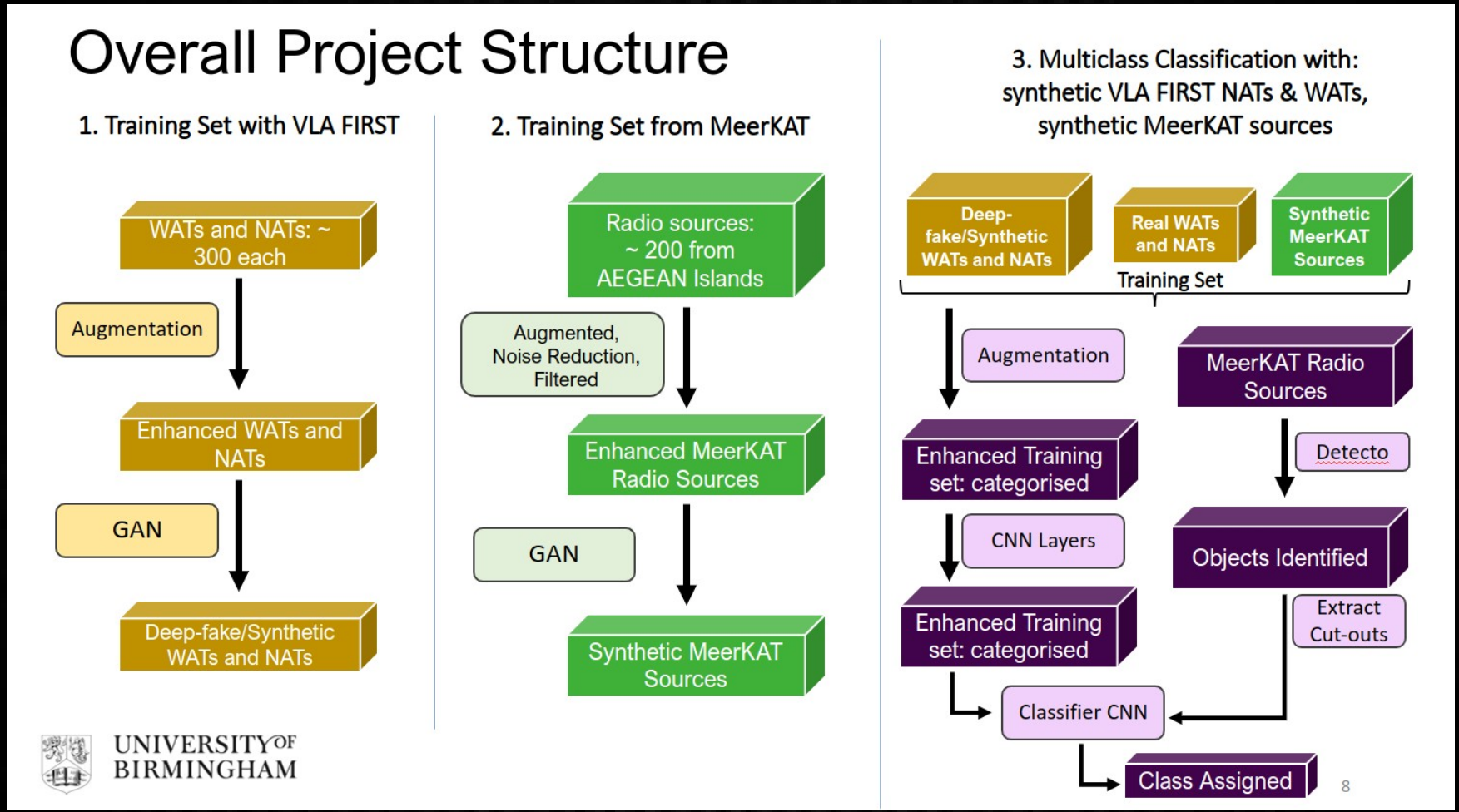
An Application



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An Application

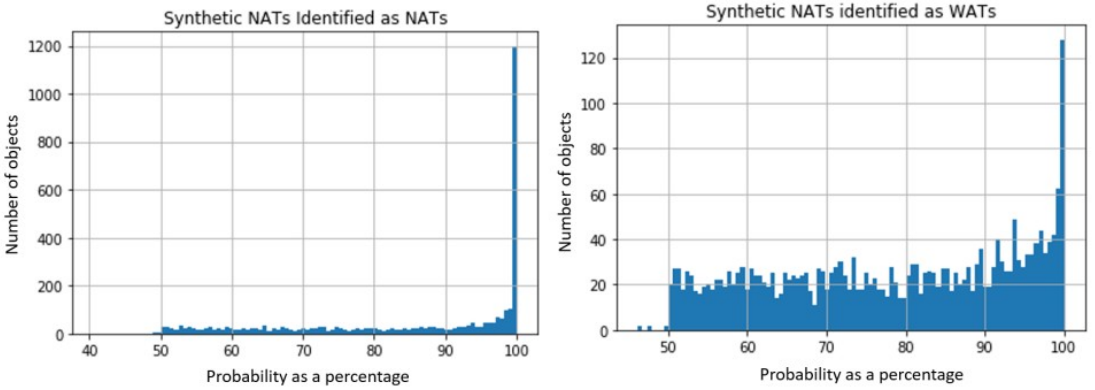

Figure 26a (*left*): Spread of synthetic NATs correctly identified as NATs.
Figure 26b (*right*): Spread of synthetic NATs identified as WATs.

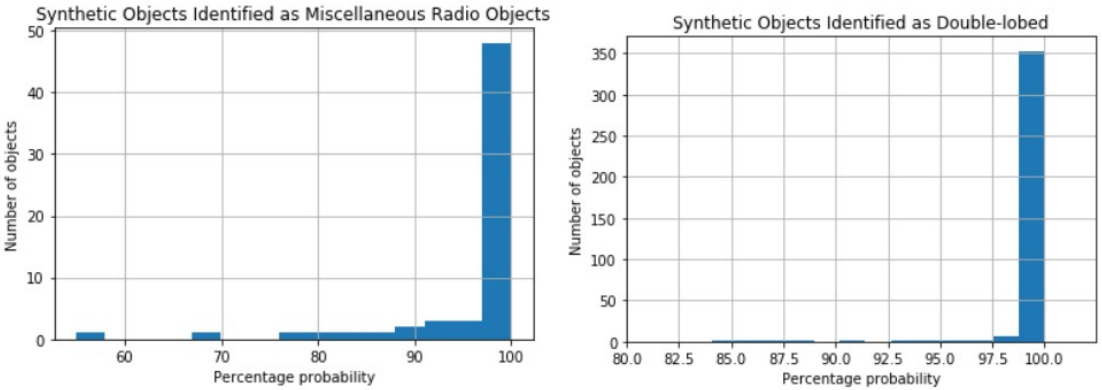

Figure 28a (*left*): Detecto cut-outs identified as miscellaneous.
Figure 28b (*right*): Detecto cut-outs identified as double-lobed radio galaxies.

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An Application

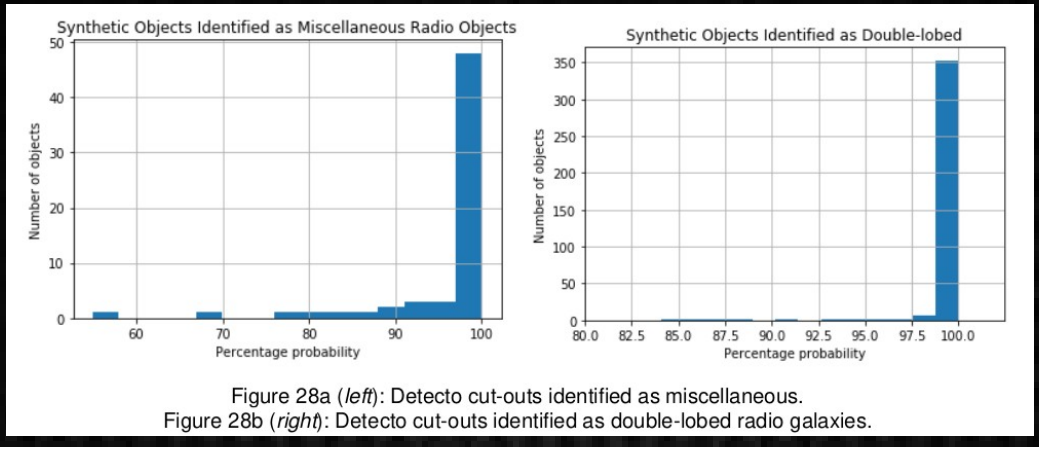

Figure 28a (*left*): Detecto cut-outs identified as miscellaneous.
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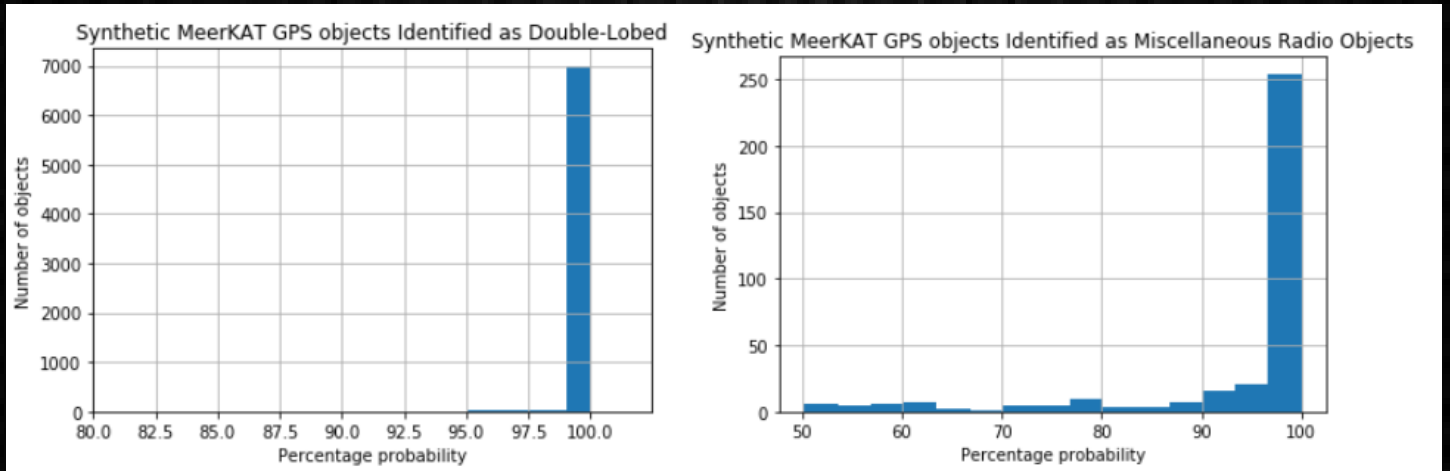

Figure 29a (*left*): Synthetic MeerKAT GPS images classified as double-lobed radio galaxies.
Figure 29b (*right*): Synthetic MeerKAT GPS images classified as miscellaneous radio objects.

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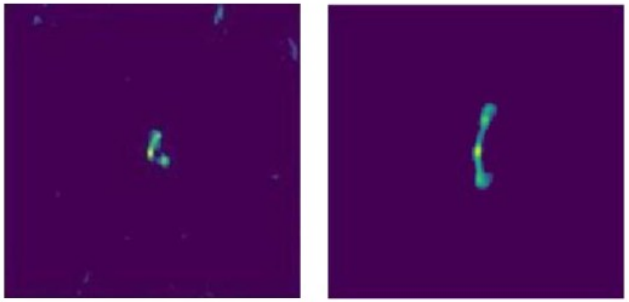
An Application



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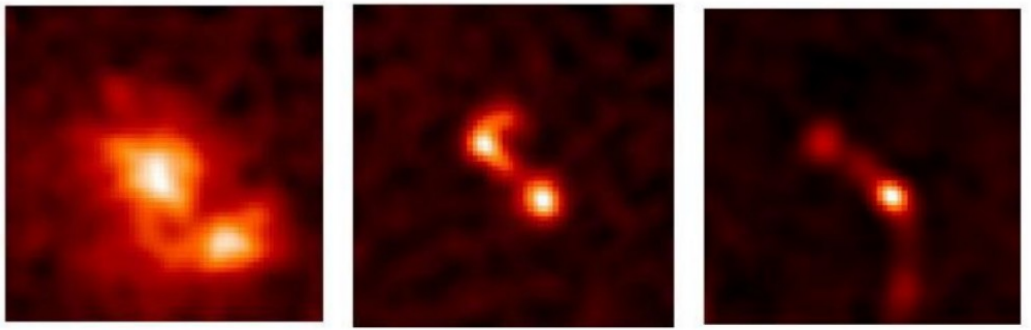


Figure 10: Examples of objects in MeerKAT GPS cut-outs.

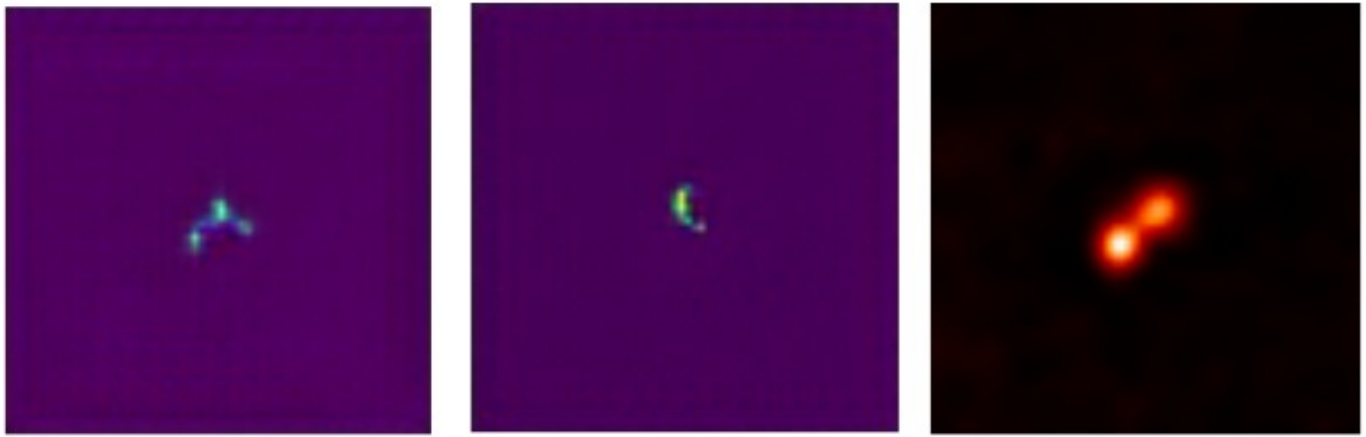


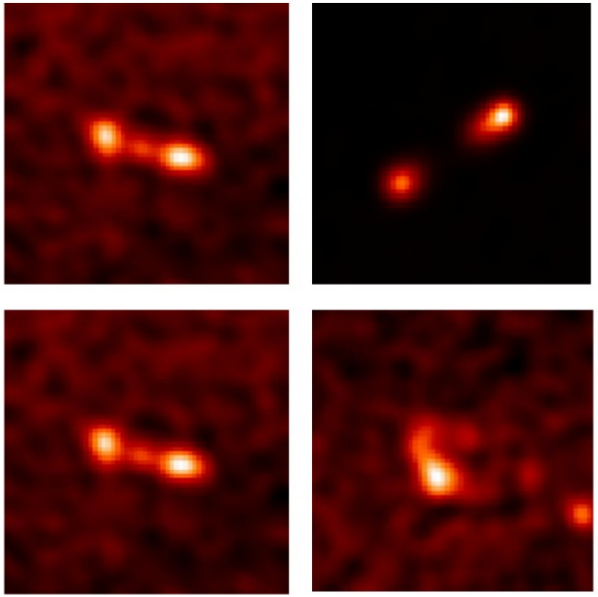
Figure 16: From left to right – a synthetic NAT, a synthetic WAT and a synthetic double-lobed radio galaxy.

An Application

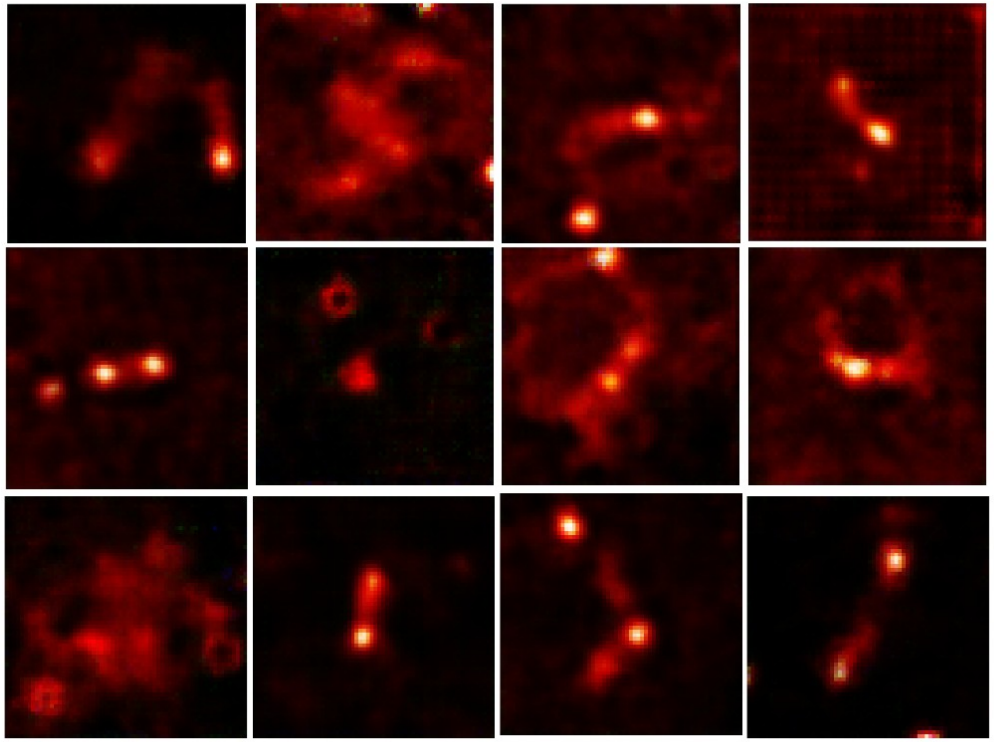
Results of GAN

MeerKAT Images

✓ Obtained cut-outs using AEGEAN islands and clusters



Synthetic MeerKAT Images:
3000 epochs



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18

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An Application

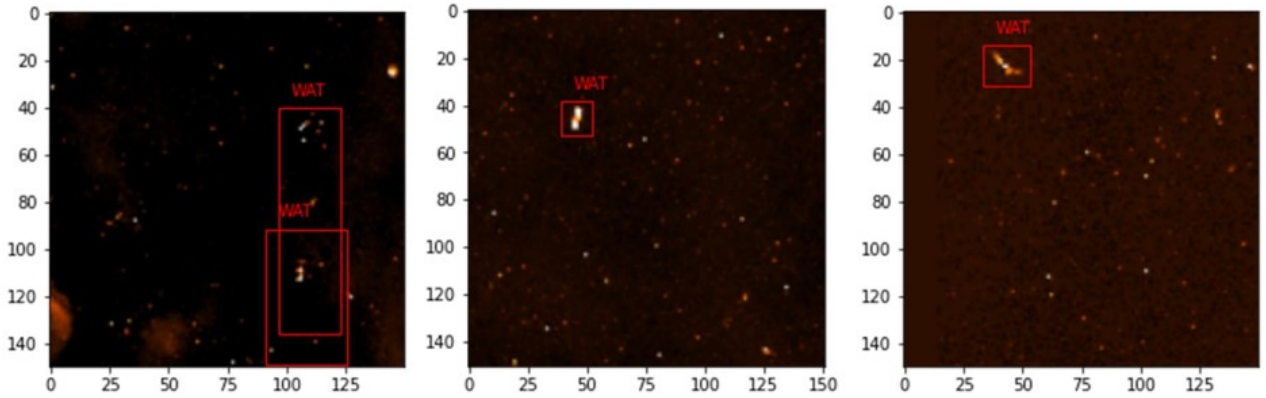
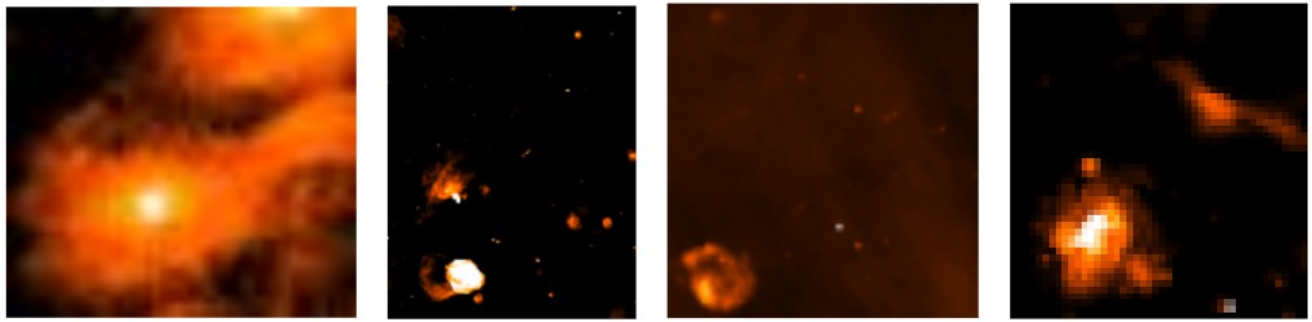


Figure 22 a, b, c (*left to right*): Examples of radio objects detected by Detecto in segments of MeerKAT GPS images. The right-most image resembles both a WAT and an FR II object.

From the objects within the bounding boxes as shown above, some of the objects within the cut-outs are shown below.



Left to right:
Figure 23a: Cut-out of object identified as NAT by Detecto.
Figure 23b: Cut-out of object identified as WAT.
Figure 23c: Cut-out of object identified as both a NAT and a WAT.
Figure 23d: Cut-out of object identified as WAT.

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Prospects with Transients

- GOTO difference photometry (?)
  Tom Killestein is/was the go-to person for this I believe (pun intended)
- Any optical/UV/X-ray image classification problem (provided there's sufficient data from surveys))
- Any photometric classification problem
- Quite a lot more
  (happy to chat later if you have ideas)

Question Time! :)

anwesha.sahu@warwick.ac.uk ; Please email me for detailed list of references, main source is my MSci dissertation