Machine Learning Methods for Radio Galaxy Classifications

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Image Courtesy : ASKAP

ASKAP Surveys

Evolutionary Map of the Universe (EMU; Norris 2021) - 1st Pilot Survey

- Covers 270 deg^2 of sky with declination
- RMS sensitivity of 25 – 35 μJy/beam
- Beamwidth of 13'' × 11'' FWHM
- ~41,000 complex radio components (~220K total)

Evolutionary Map of Universe (EMU) will detect >40 million radio galaxies over next 5 years!

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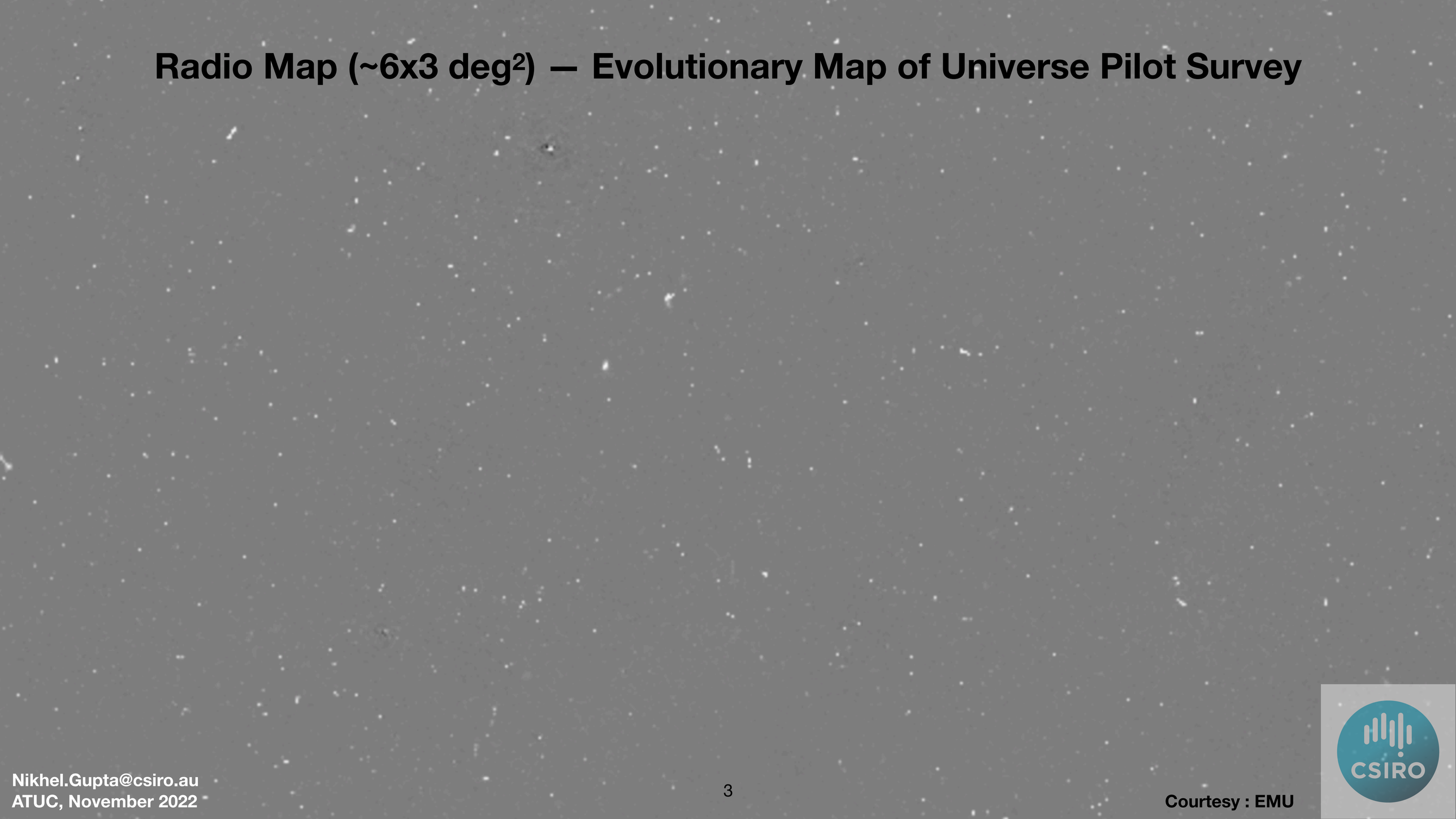
Courtesy : ASKAP

Radio Map (~6x3 deg^2) — Evolutionary Map of Universe Pilot Survey



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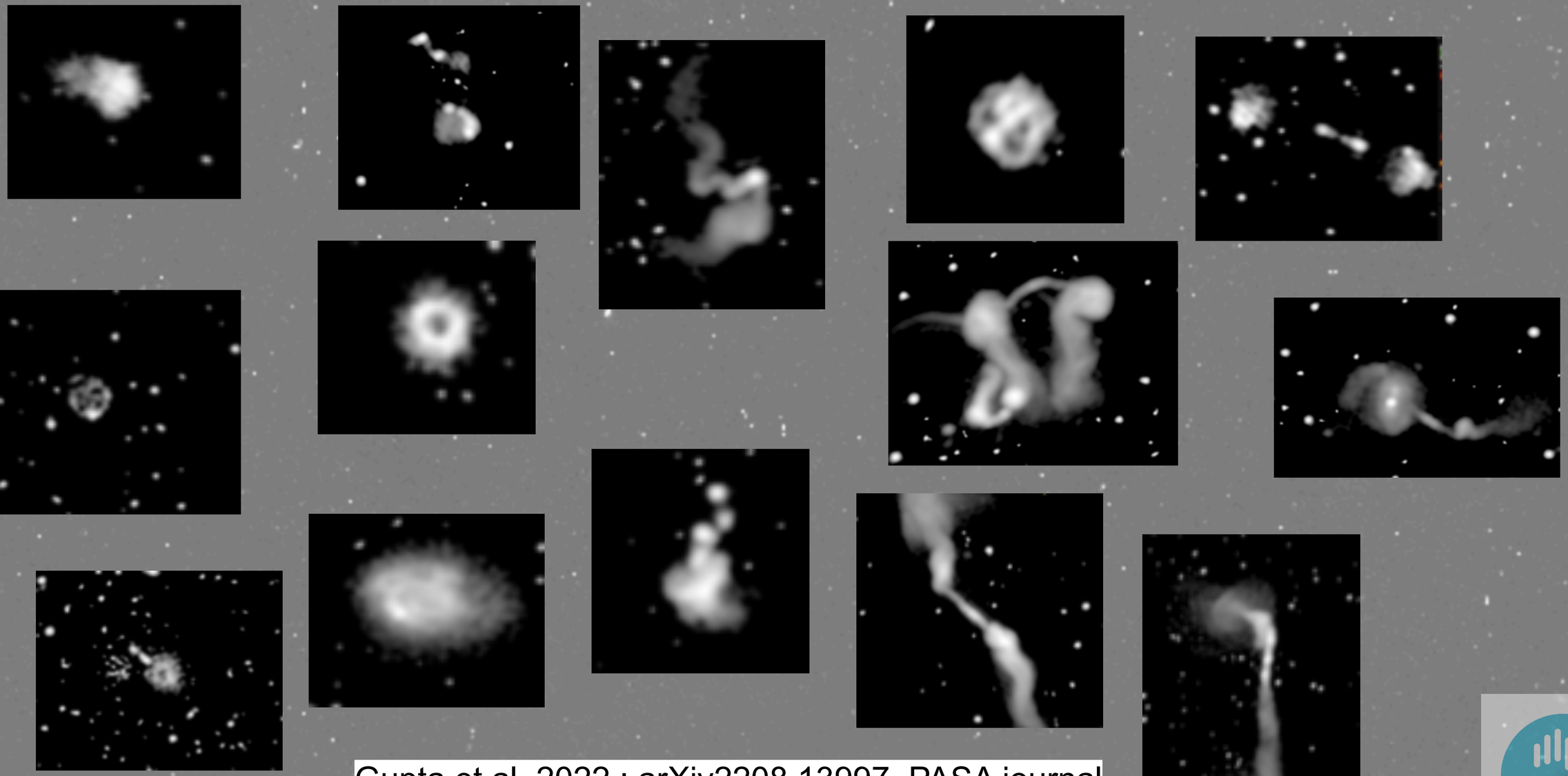
Courtesy : EMU

Radio Map (~6x3 deg^2) — Evolutionary Map of Universe Pilot Survey



Gupta et al. 2022 : arXiv2208.13997, PASA journal

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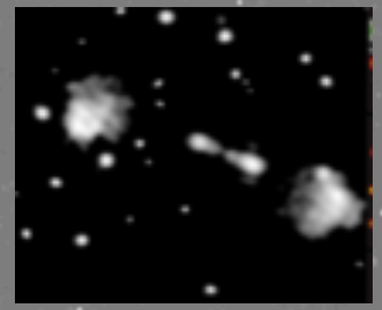
Radio Map (~6x3 deg^2) — Evolutionary Map of Universe Pilot Survey



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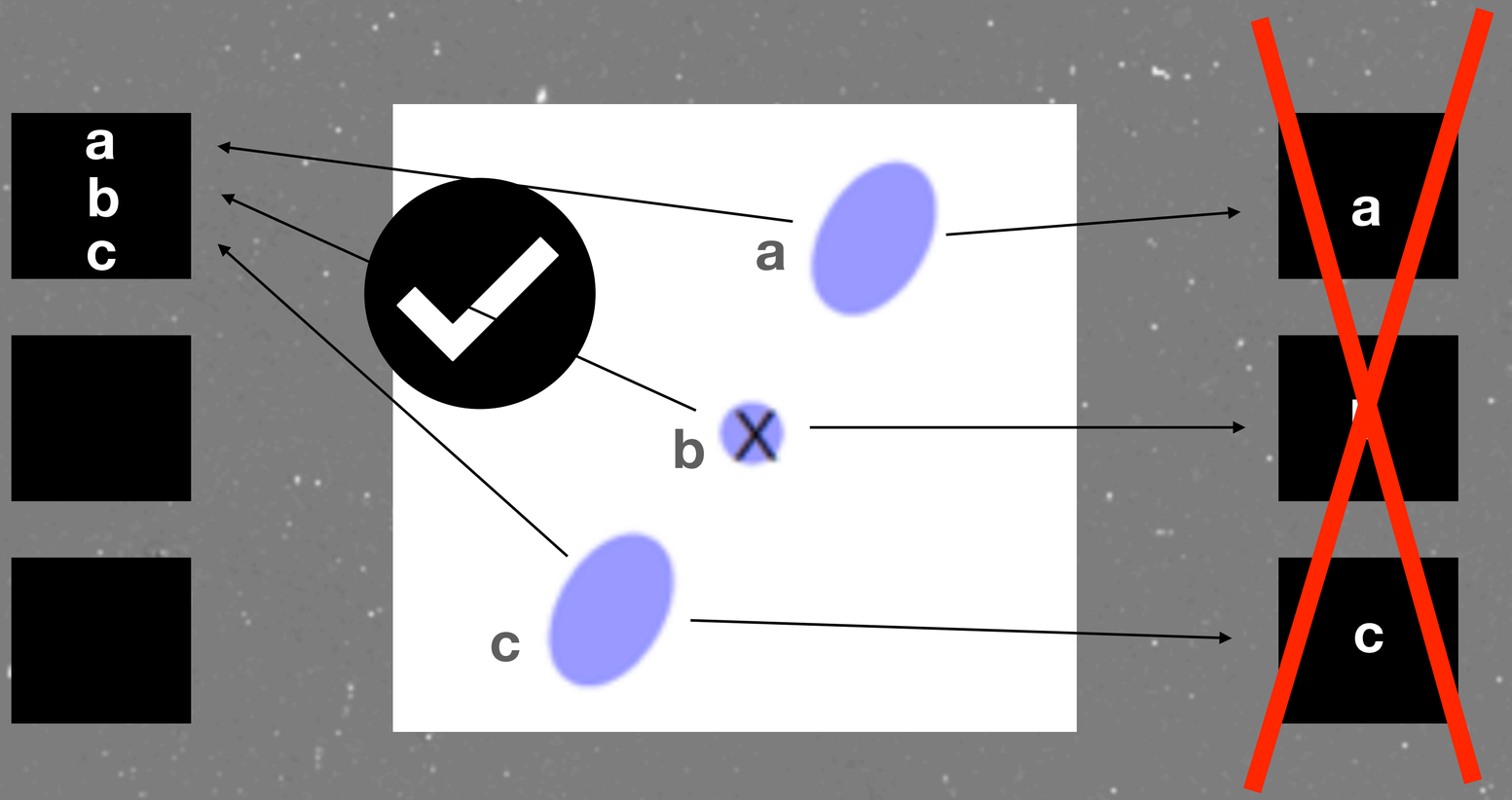
Courtesy : EMU

Can we group components of Radio Galaxies using ML?



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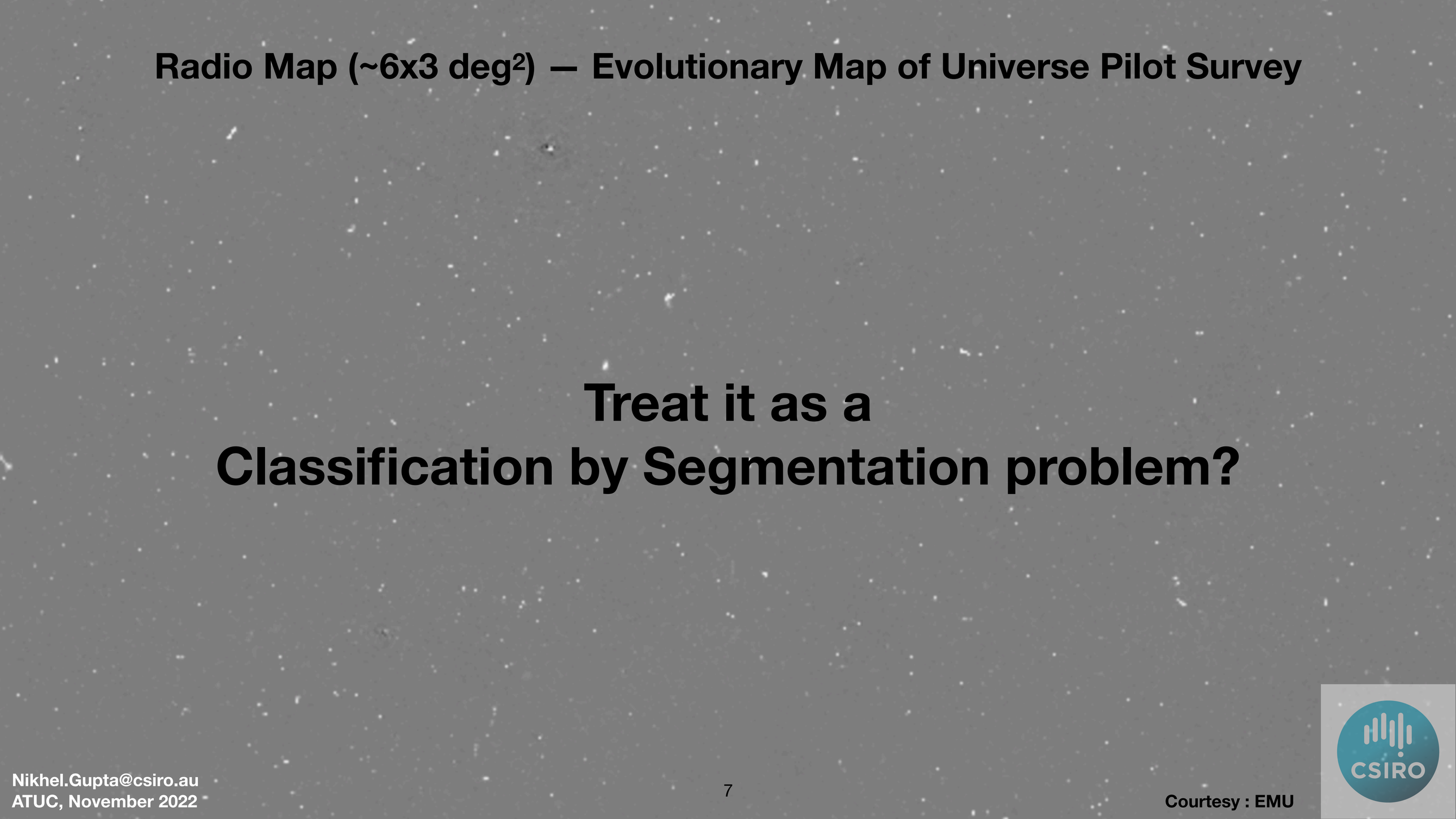
Courtesy : EMU

Radio Map (~6x3 deg^2) — Evolutionary Map of Universe Pilot Survey



Treat it as a
Classification by Segmentation problem?

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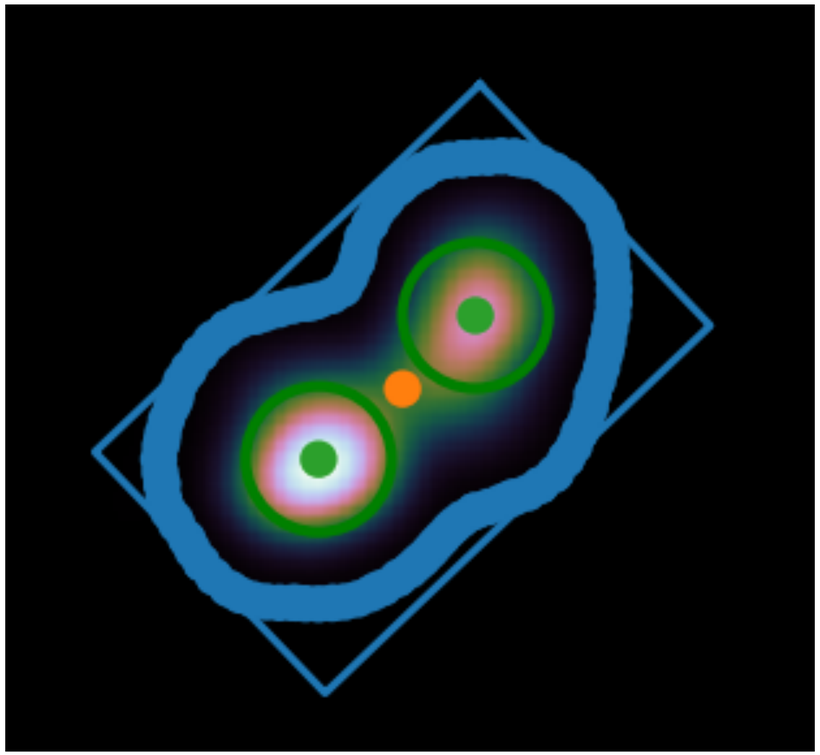
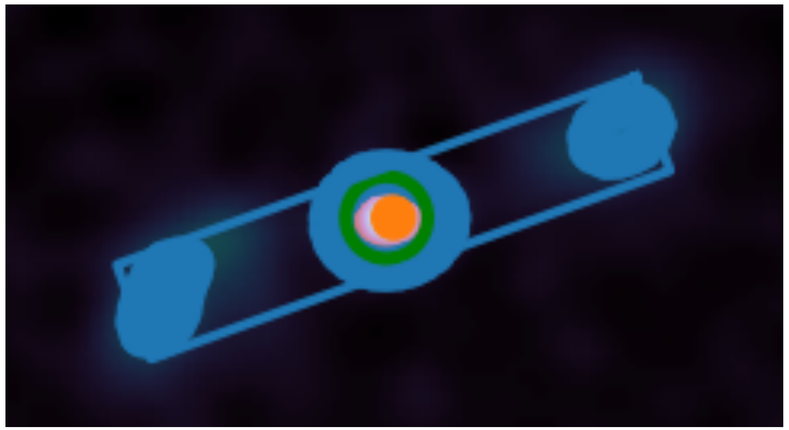
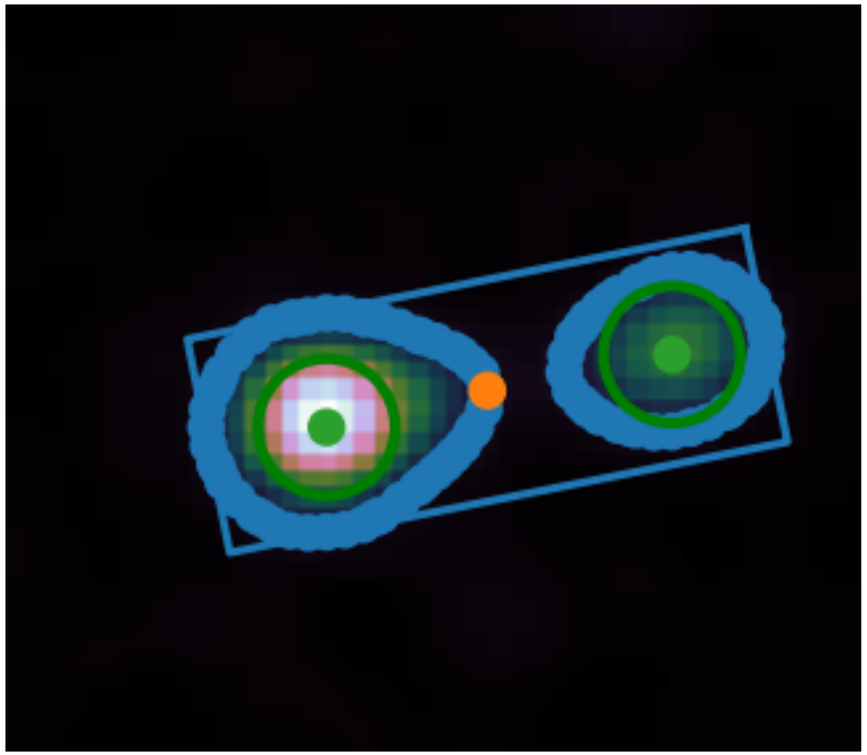
Courtesy : EMU

What data do we have?







DRAGNs Catalog
~500 sources with boxes and Infrared source positions

Yew M., Norris R. et al. in prep

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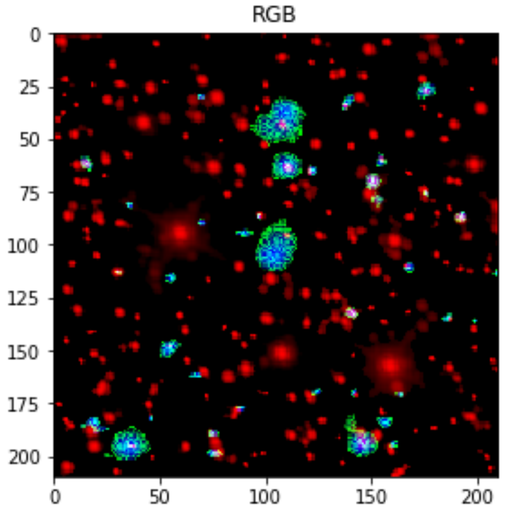
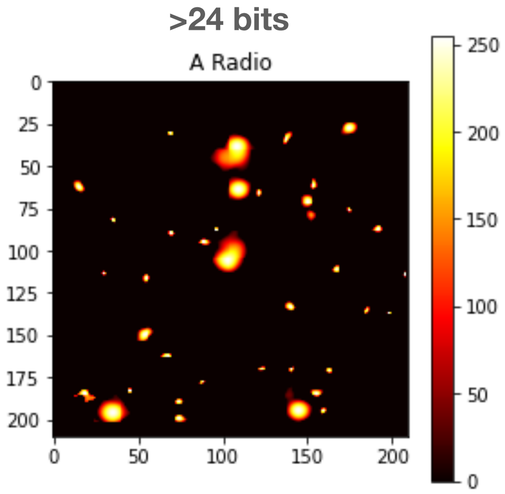
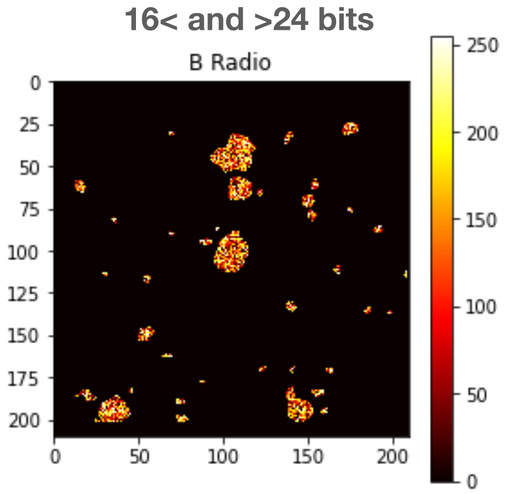
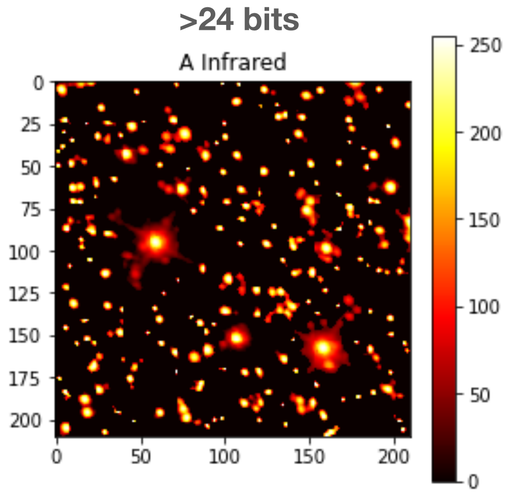
DRAGNs Catalog —> RadioGalaxyNET (coco format)

Four Classes: FRI, FRII, FRx, S





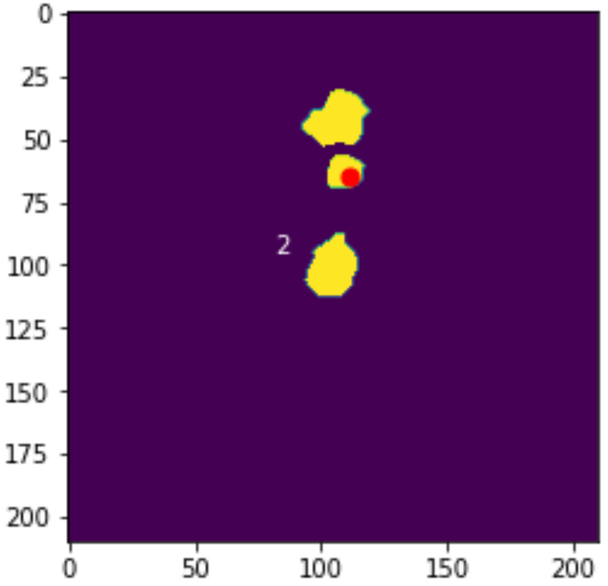




Class-level label

FRII

+



Pixel-level label
(Radio segmentation mask + IR key points)

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Can we group components of Radio Galaxies using ML?

- **Supervised Learning**
  Complete information of truth-labels is available for all images
- **Self-supervised Learning**
  No information about truth-labels is available for all images
- **Weakly-supervised Learning**
  Some information about truth-labels is available for all images
- **Semi-supervised Learning**
  Complete information of truth-labels is available for some images

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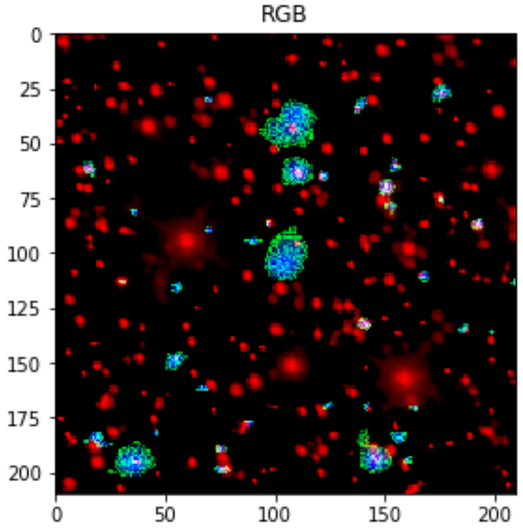
Courtesy : EMU

Supervised Learning

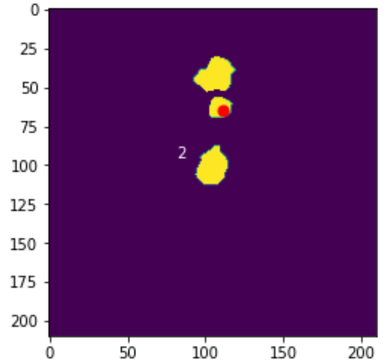


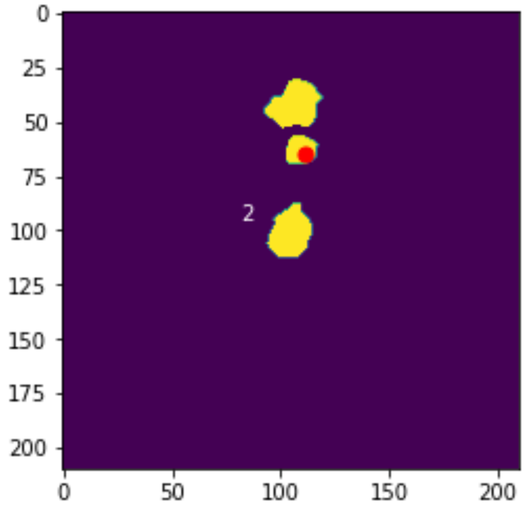
+

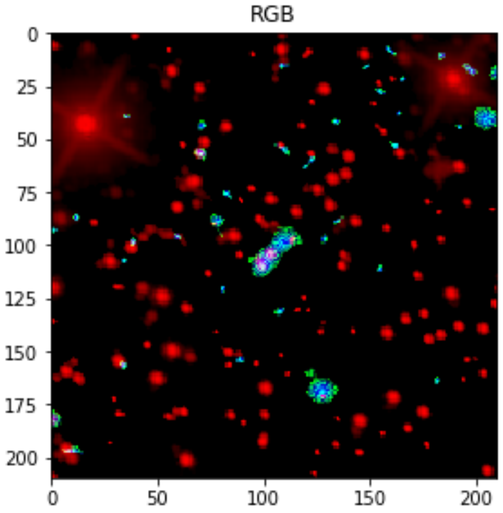
Class-level label

FRII

Segmentation Mask & Keypoints





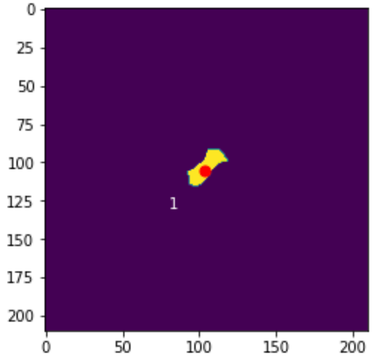


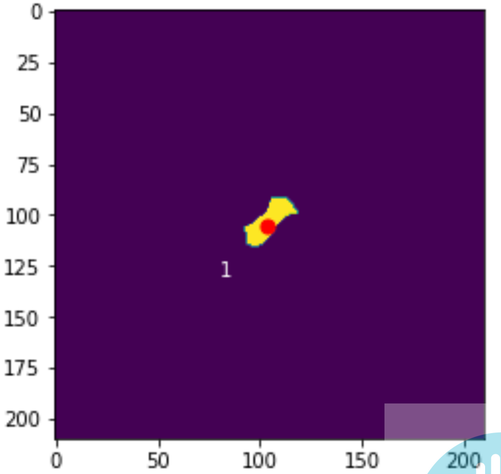
+

Class-level label

FRI

Segmentation Mask & Keypoints





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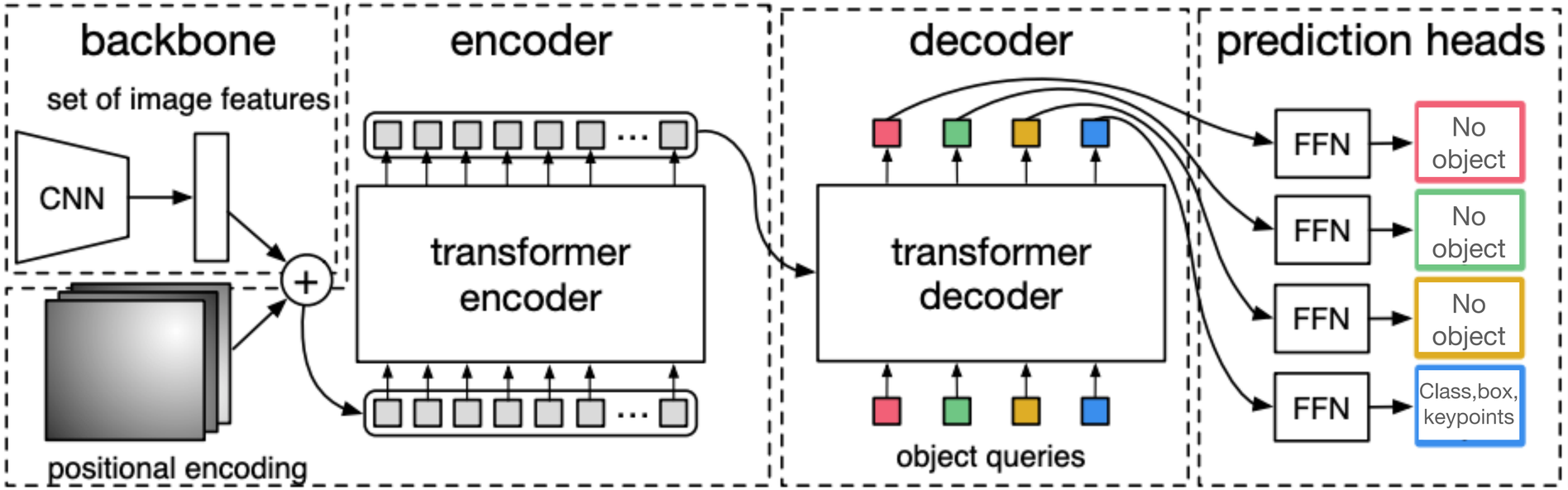
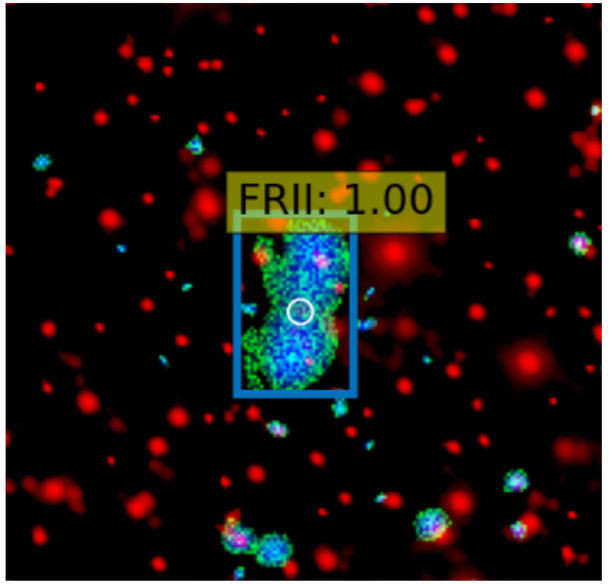
Supervised Learning
(End to End detection with Transformers e.g. DETR)





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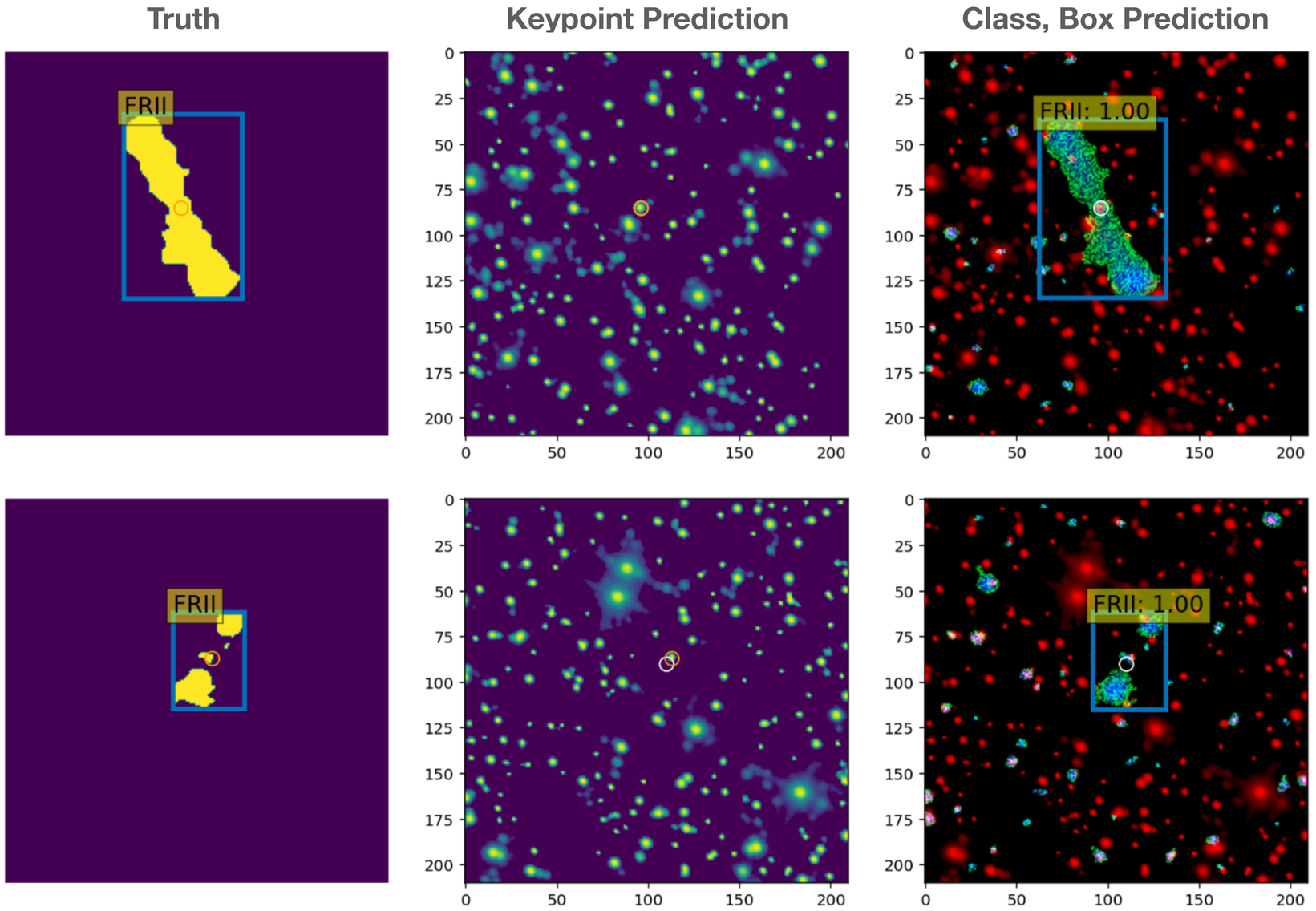
Supervised Learning - kDETR Results



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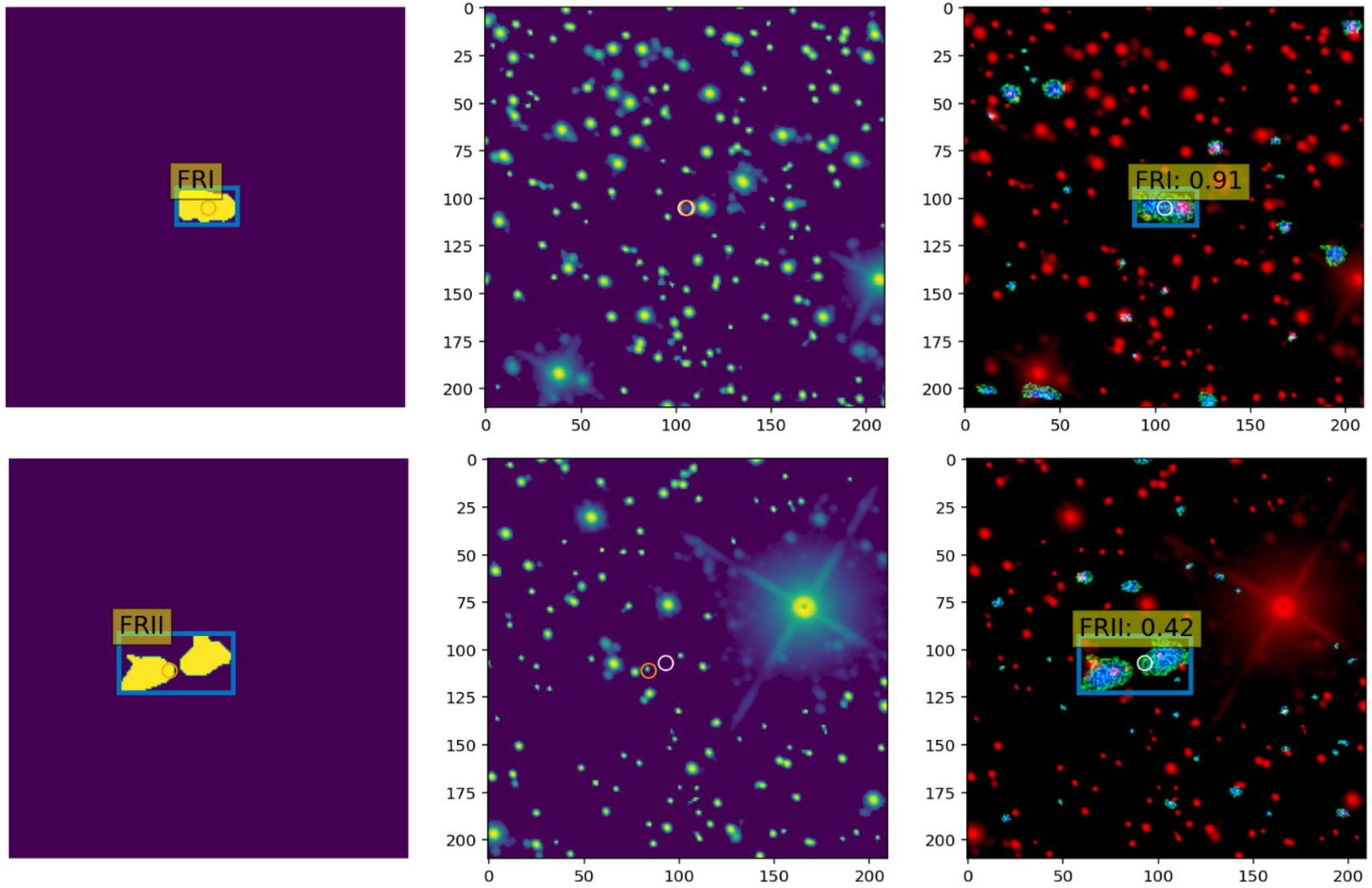
Supervised Learning - kDETR Results

Truth | Keypoint Prediction | Class, Box Prediction



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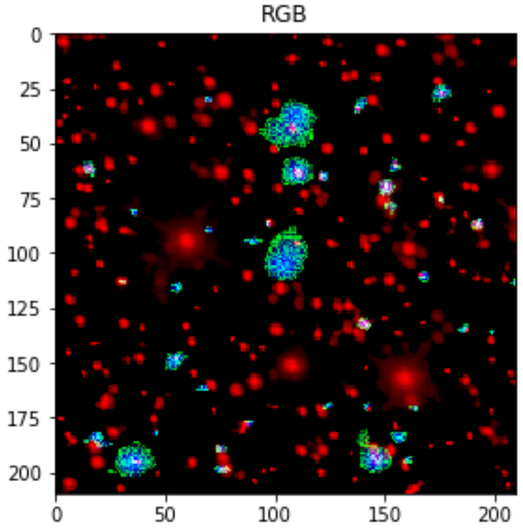
Weakly-supervised Learning

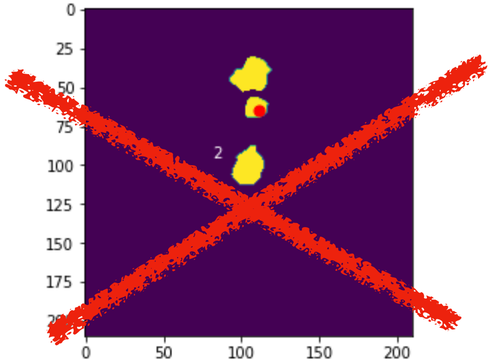


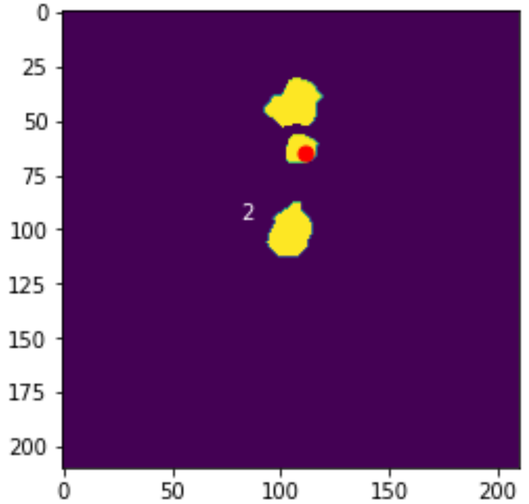
+

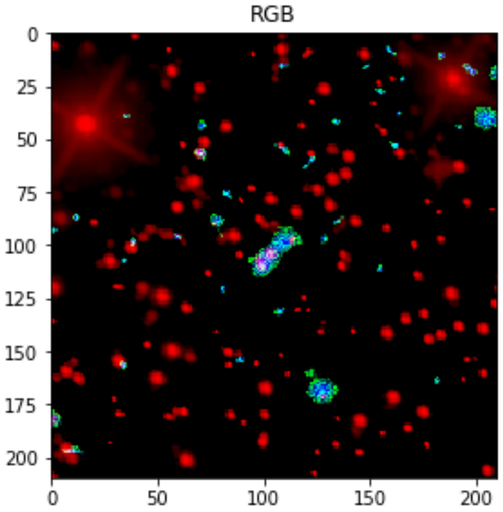
Class-level label

FRII

Segmentation Mask & Keypoints





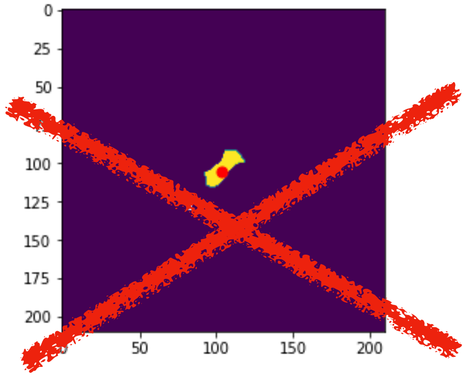


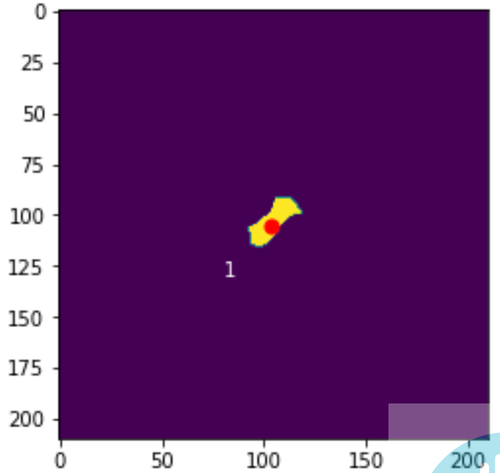
+

Class-level label

FRI

Segmentation Mask & Keypoints





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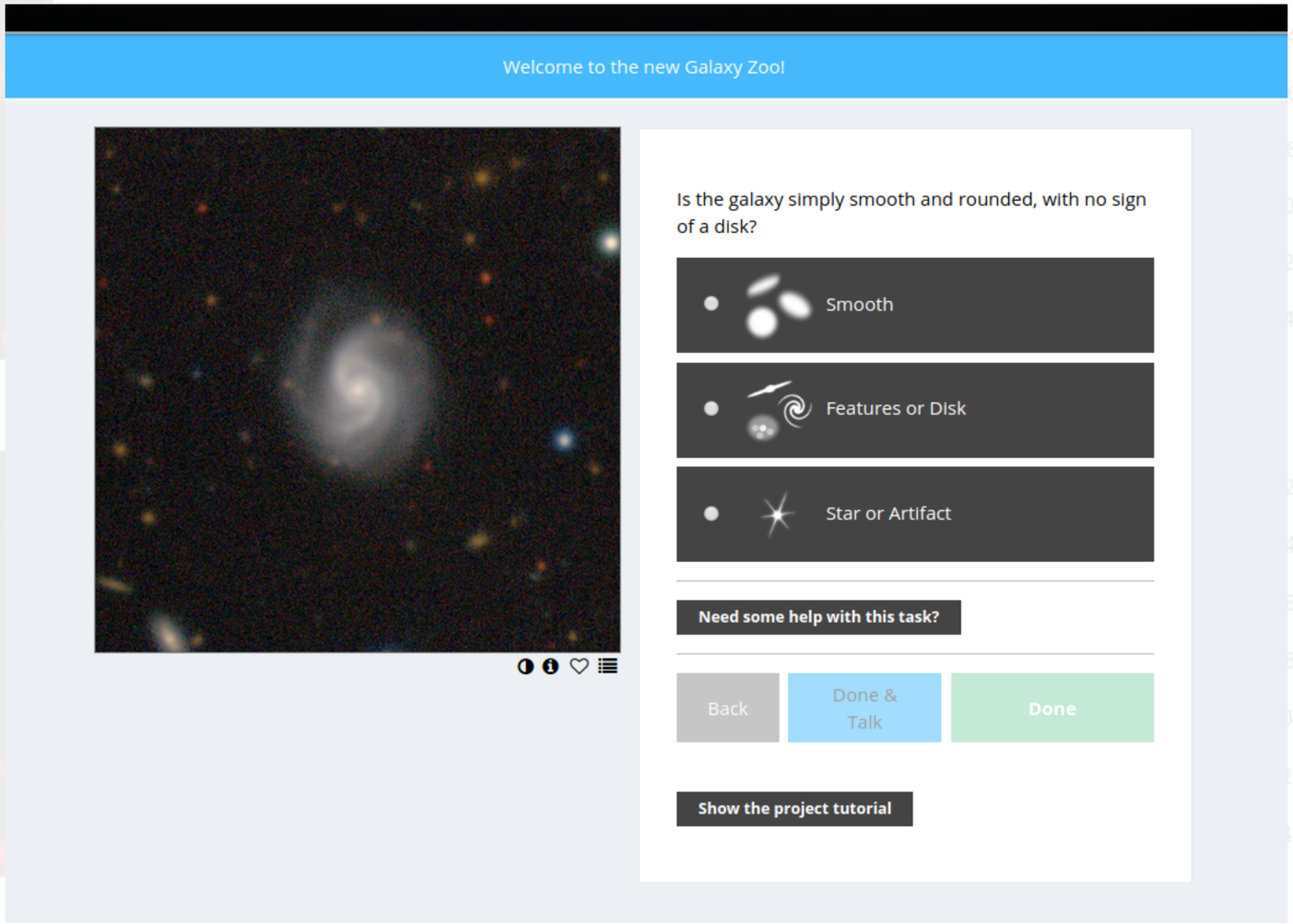
Weakly-supervised Learning (e.g. ReCAM)

Citizen Science



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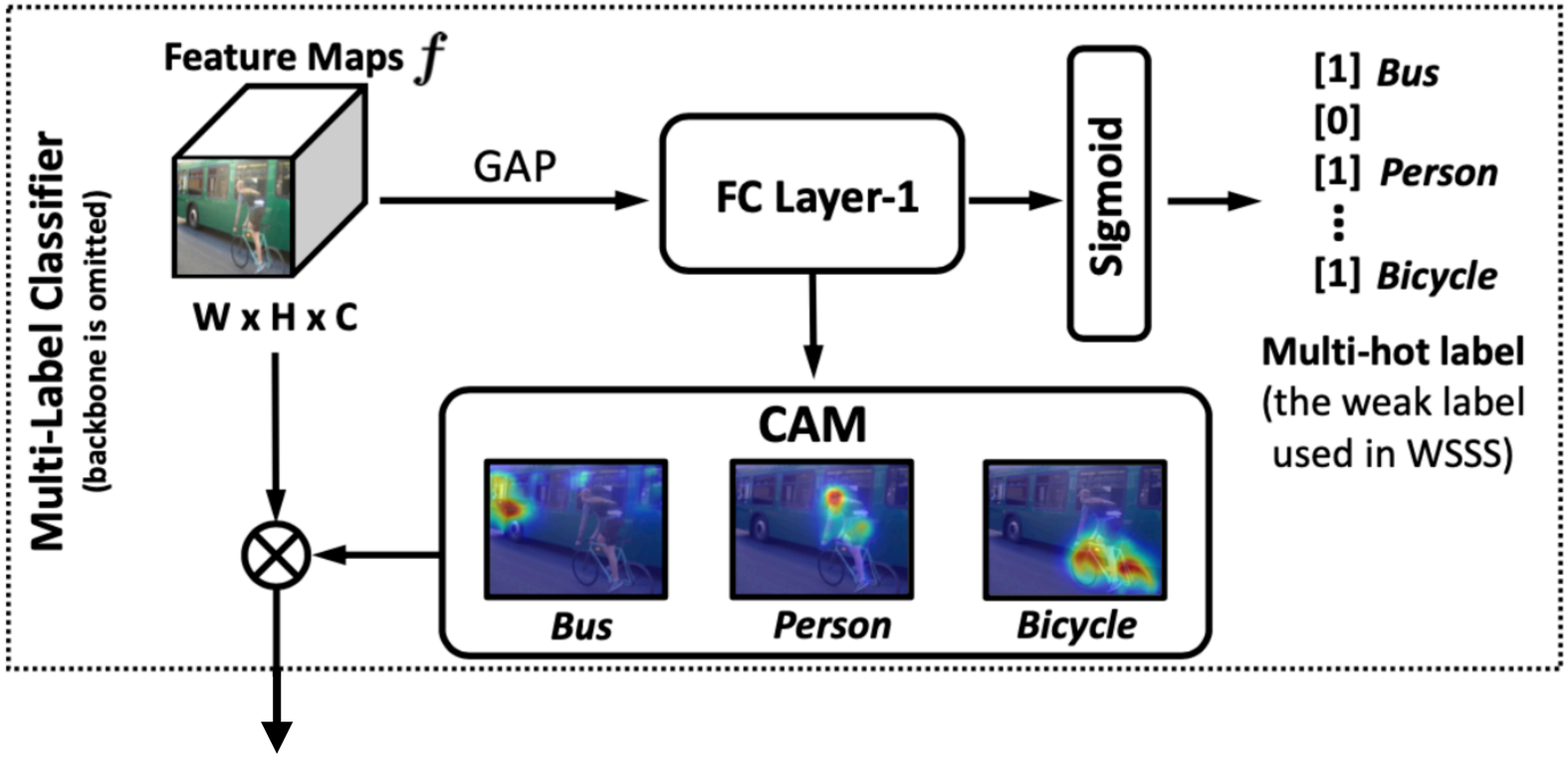
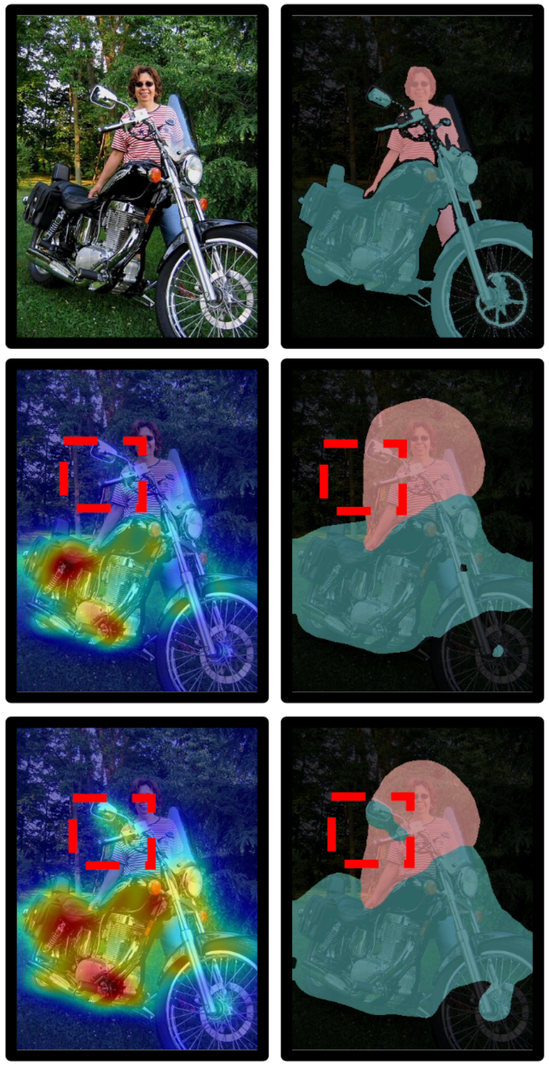
Weakly-supervised Learning
Class Activation Maps



Further refinements
e.g. IRN, AdvCAM, ReCAM



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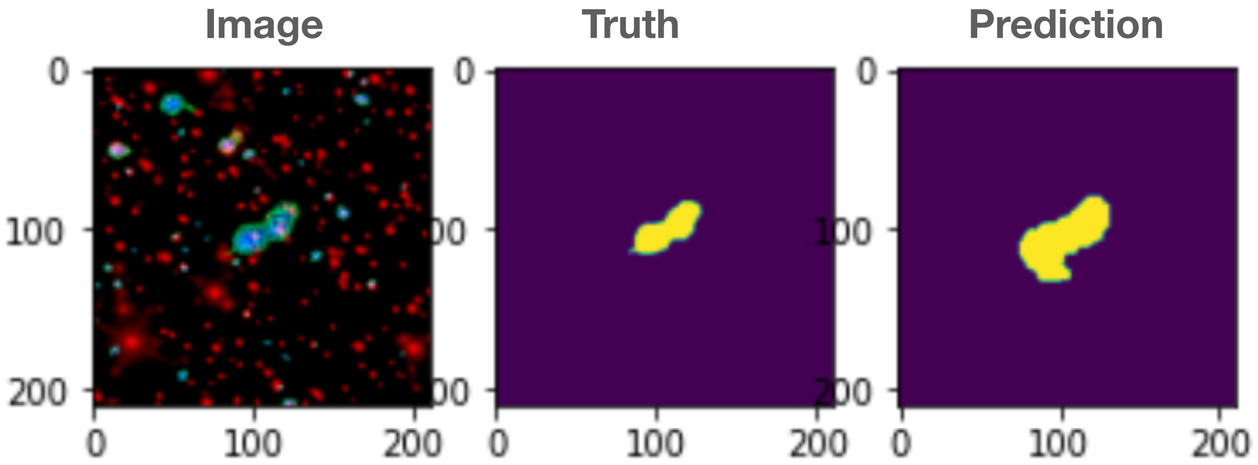
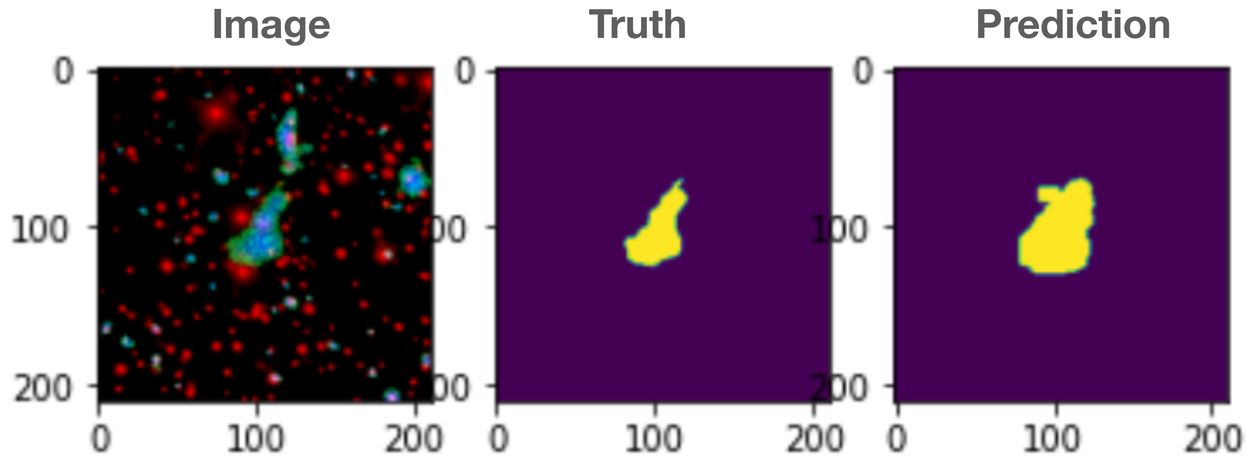
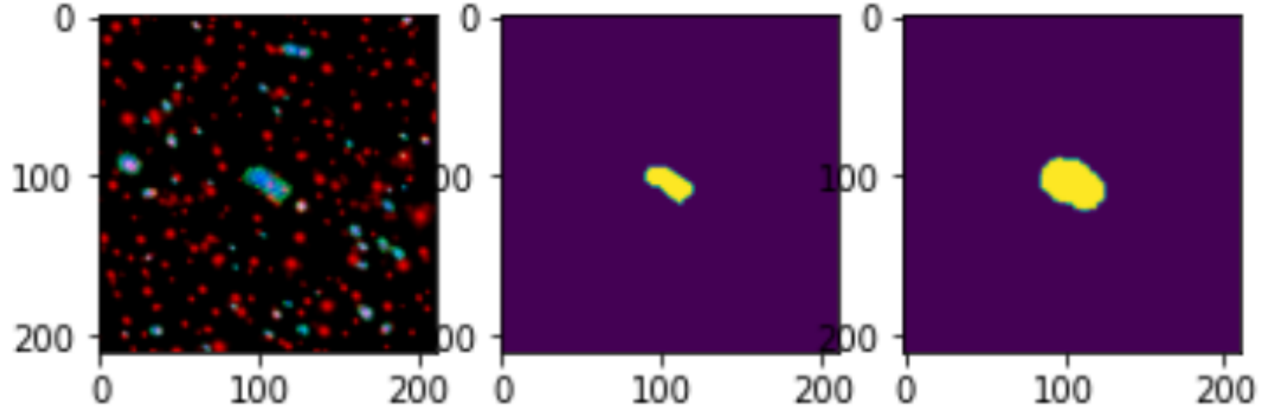
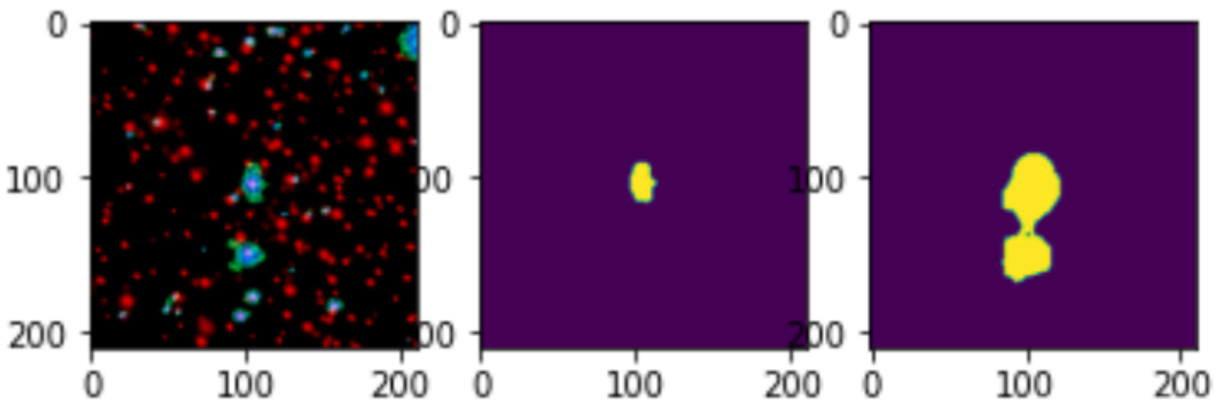
Weakly-supervised Learning - ReCAM Results









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Summary

- Grouping multiple components of the same galaxy is required to construct useful Radio Galaxy Catalogs from Next Generation of Radio Surveys.

- Classification by Segmentation methods produce encouraging results.

Future Work:

- ~2500 more sources in the DRAGNs catalog.
- Add keypoint detection for Infrared source identification in weakly-supervised networks.
- Use non-labelled data for Semi-Supervised Learning.
- Generate Radio Galaxy Catalog for EMU.
- Continue for other ASKAP surveys and other telescopes to generate a generalised solution.