Mergers and AGNs in the HSC-SSP: Do Mergers Trigger AGN Activity?

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初代星・初代銀河研究会2023

Results are preliminary!

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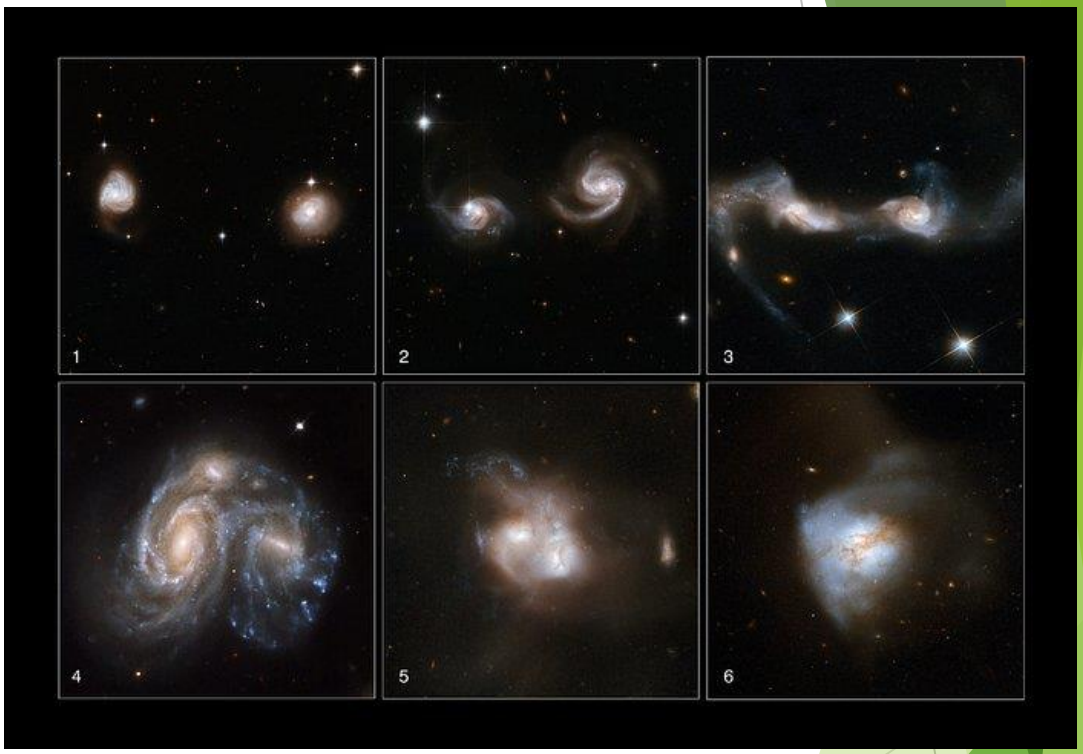
Background – Galaxy Interactions

- **Galaxies evolve**
- The commonly accepted pathway for structure growth is through **hierarchical growth – smaller objects grow through accretion**
- Galaxies interact/merge with other galaxies form a new galaxy



Credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University), K. Noll (STScI), and J. Westphal (Caltech)

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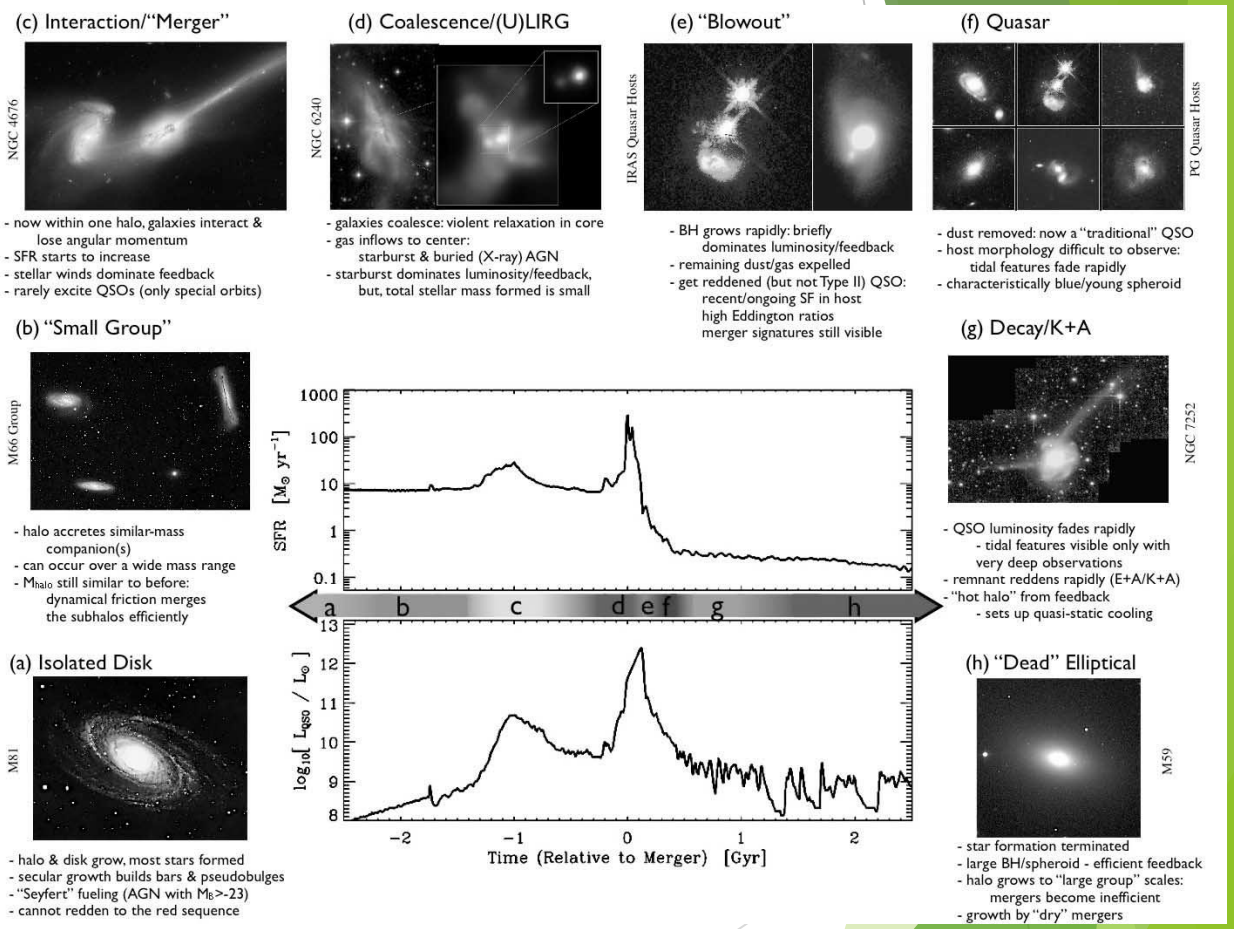

Credit: Hopkins et al. (2008)

Galaxy Interactions and AGN

- The gas inflows caused by galaxy interactions and mergers **are considered to accelerate the accretion onto supermassive black holes**
- As such, it is considered that a strong connection exists **between merger activity and AGN activity**

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Sample Selection

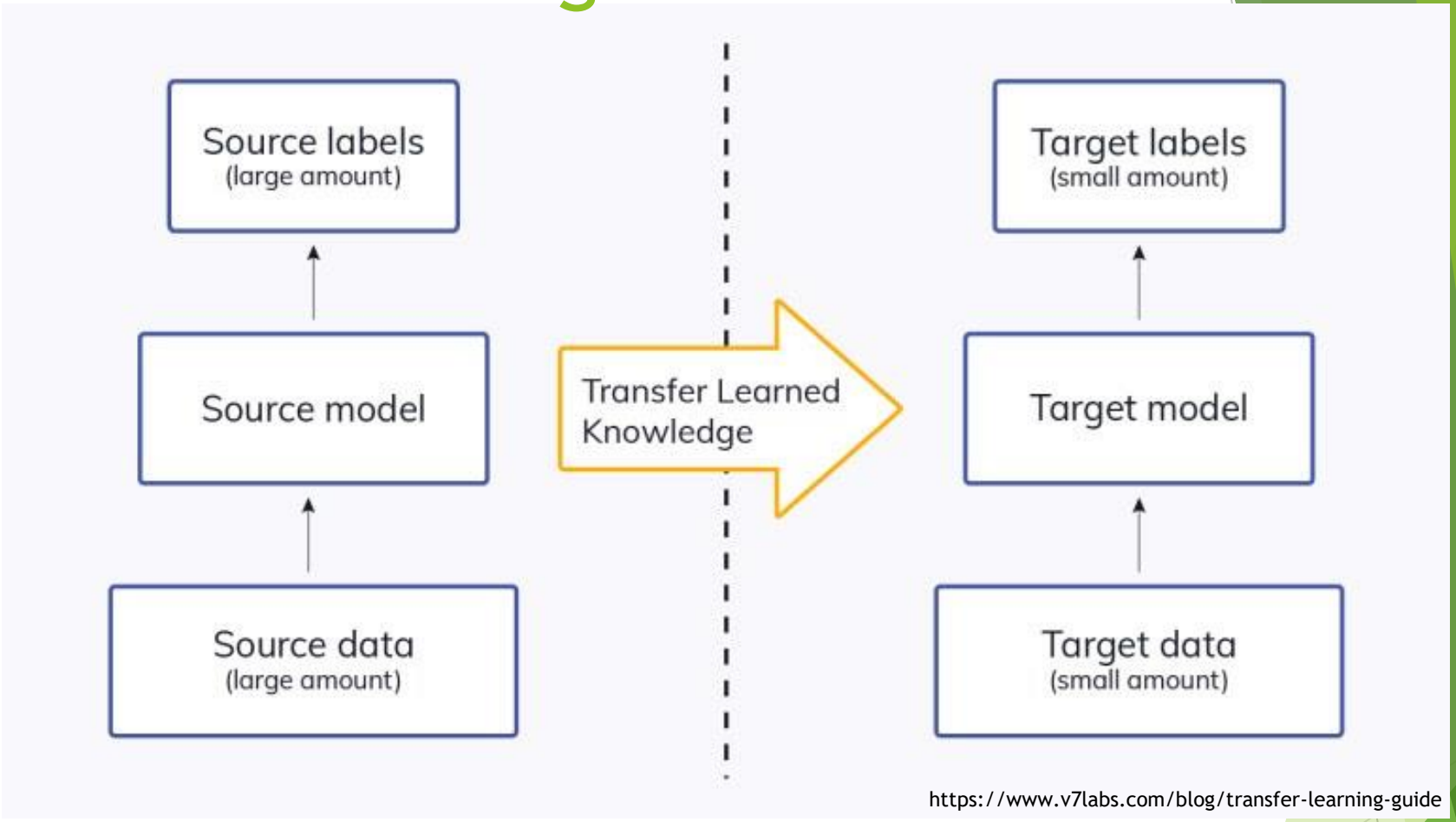
- ~120,000 Galaxy samples cross matched between **HSC-SSP PDR3** and **GAMA DR4**
- This sample assures spectroscopic redshifts *(z*<0.3), MAGPHYS stellar masses
  - **Merger Selection** – Omori et al. (2023) in press. merger probabilities
  - **AGN Selection** – PROSPECT SED Fitting

Interacting Galaxy Classification – Machine Learning

- Using **Convolutional Neural Networks** to classify interacting galaxies
  - Strengths:
    - Time and human-resource efficient method of visual classification
  - Weaknesses
    - Depth and resolution of imaging is important
    - Requires a large dataset to achieve sufficient accuracy
    - “Ground truths” of training datasets may not be accurate

https://blog.galaxyzoo.org/2018/03/06/gems-of-the-galaxy-zoos-coming-soon-to-a-space-telescope-near-your-planet/

Transfer Learning



https://www.v7labs.com/blog/transfer-learning-guide

- Re-using a pre-trained model as a starting point for a new task
  - Examples: ImageNet, AlexNet
- Transfer learning for merger classification has been used in galaxy studies (Ackerman et al. 2018)

Merger Probabilities- Zoobot (Walmsley et al. 2022) trained model (Omori et al. 2023)

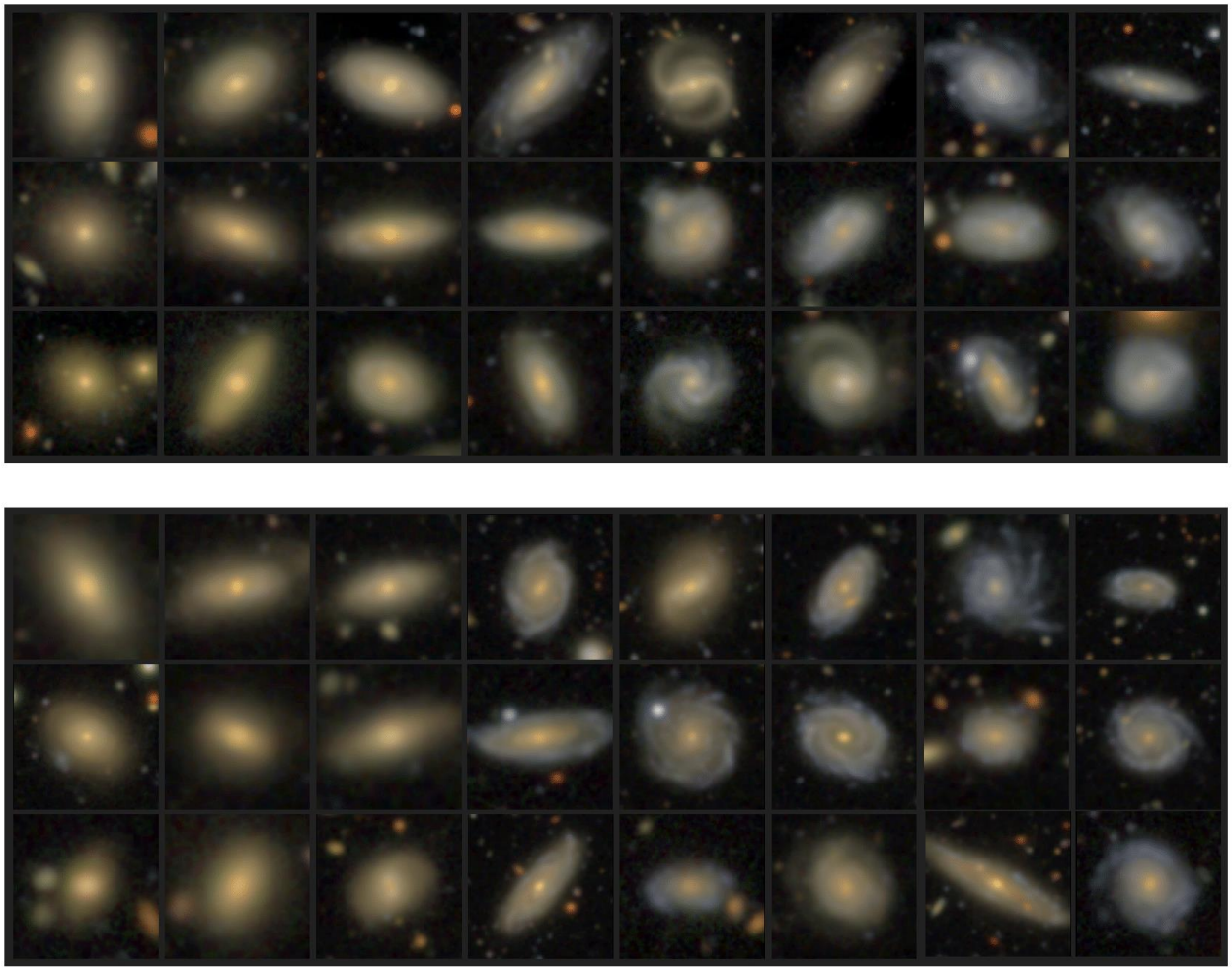
- Network pre-trained on **Galaxy Zoo DECaLS images** and their 96 million clicks
- General transfer learning improves classification accuracies (Ackerman et al. 2018), **fine-tuning** models pre-trained on galaxy images can further improve accuracies

Standard transfer learning:

Zoobot:

Training Data

- Model fine-tuned with “ground truth” images
  - Simulation mock images that are “observation-ised”
    - Illustris TNG50 mock images that are “HSC-ized”



Credit: Rhythm Shimakawa – NAOJ, Bottrell+ (2023)

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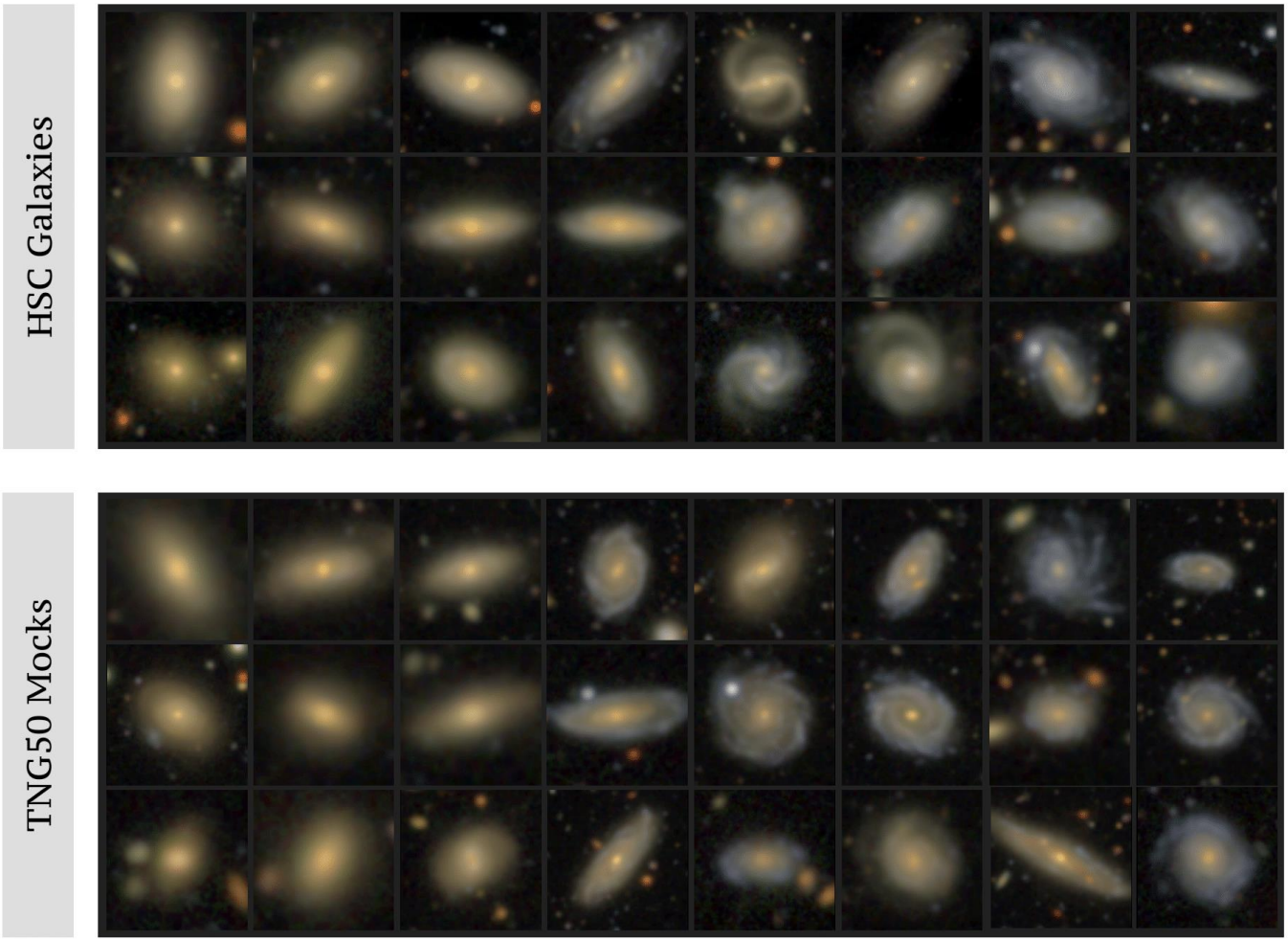

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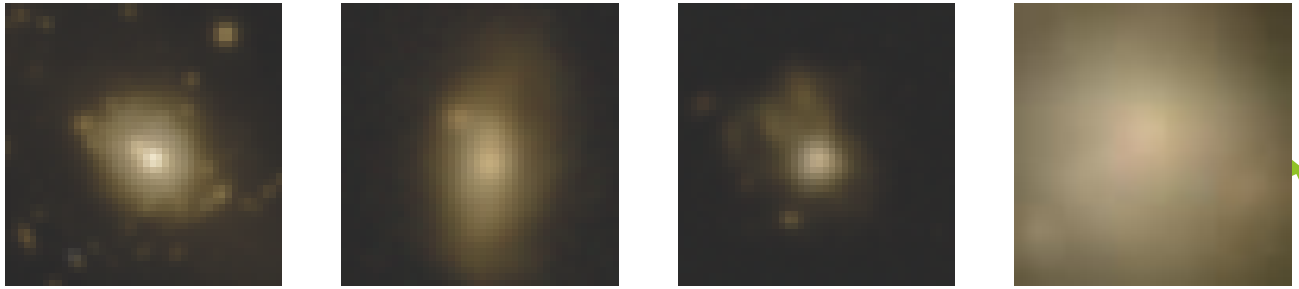
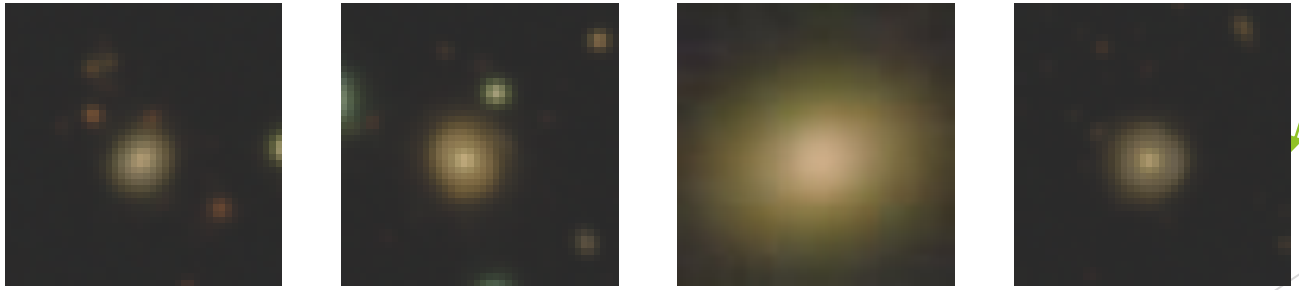


Non-mergers: > 3 Gyr since/until closest merger event



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x 4 viewing angles
= 1164 fine tuning samples per class

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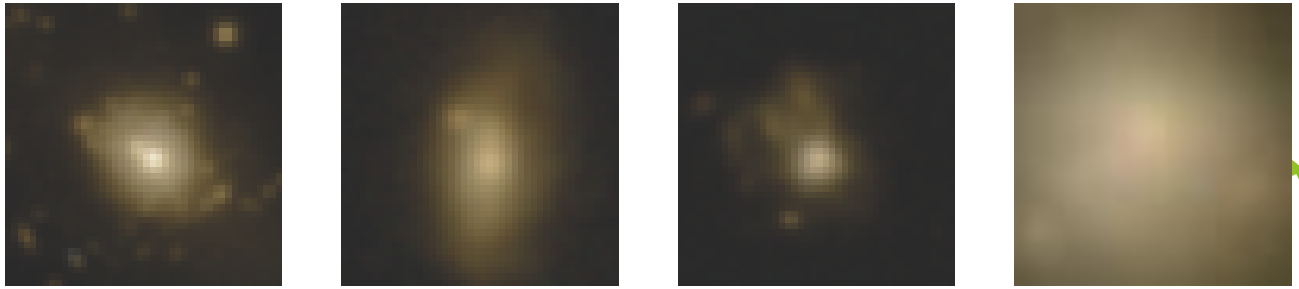

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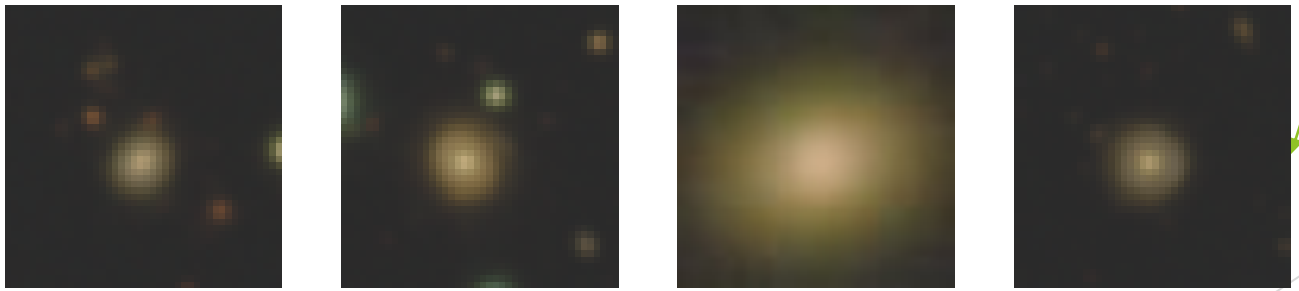

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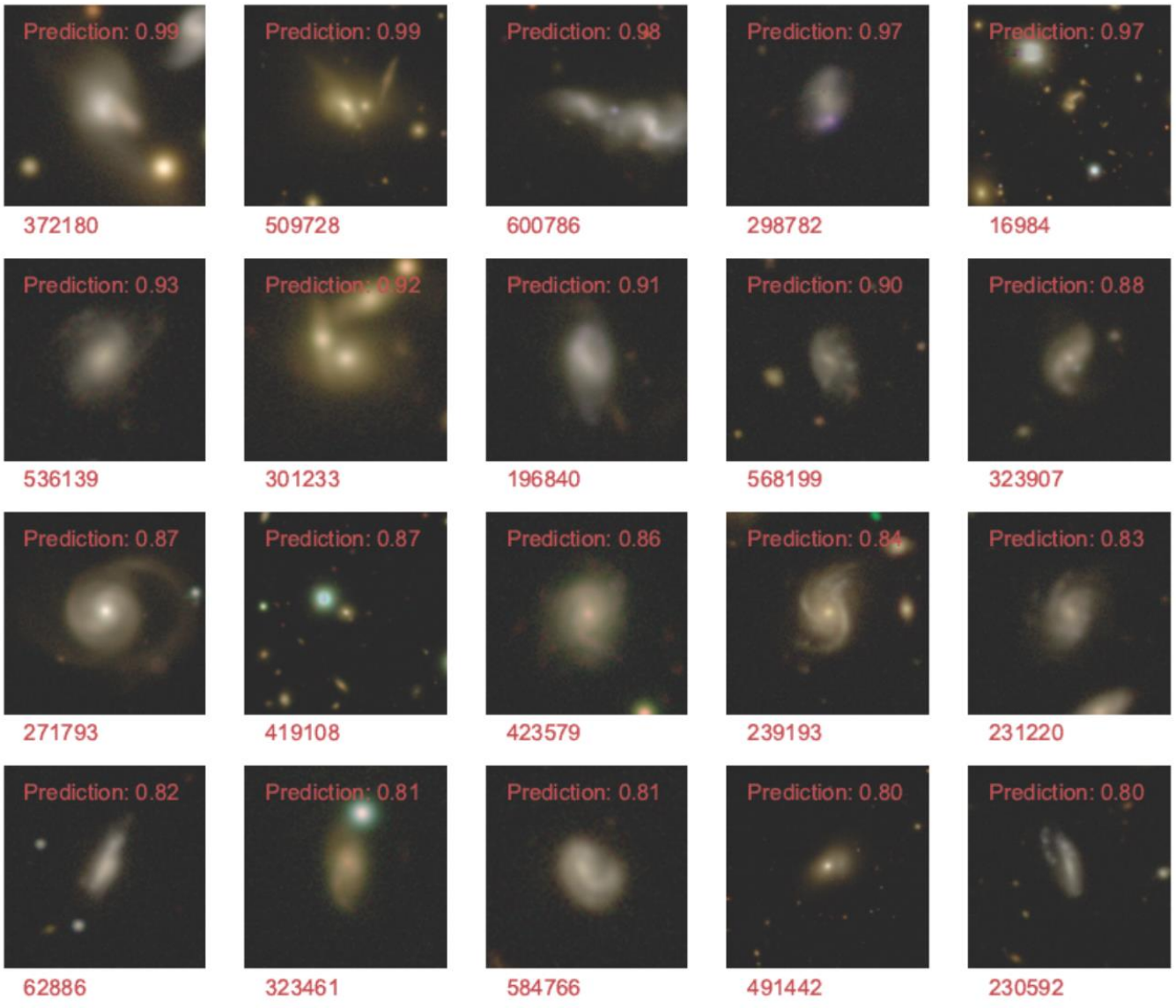
76% accuracy

Results – Classification

- We have applied our model and made predictions for ~300,000 HSC S21A images – merger examples



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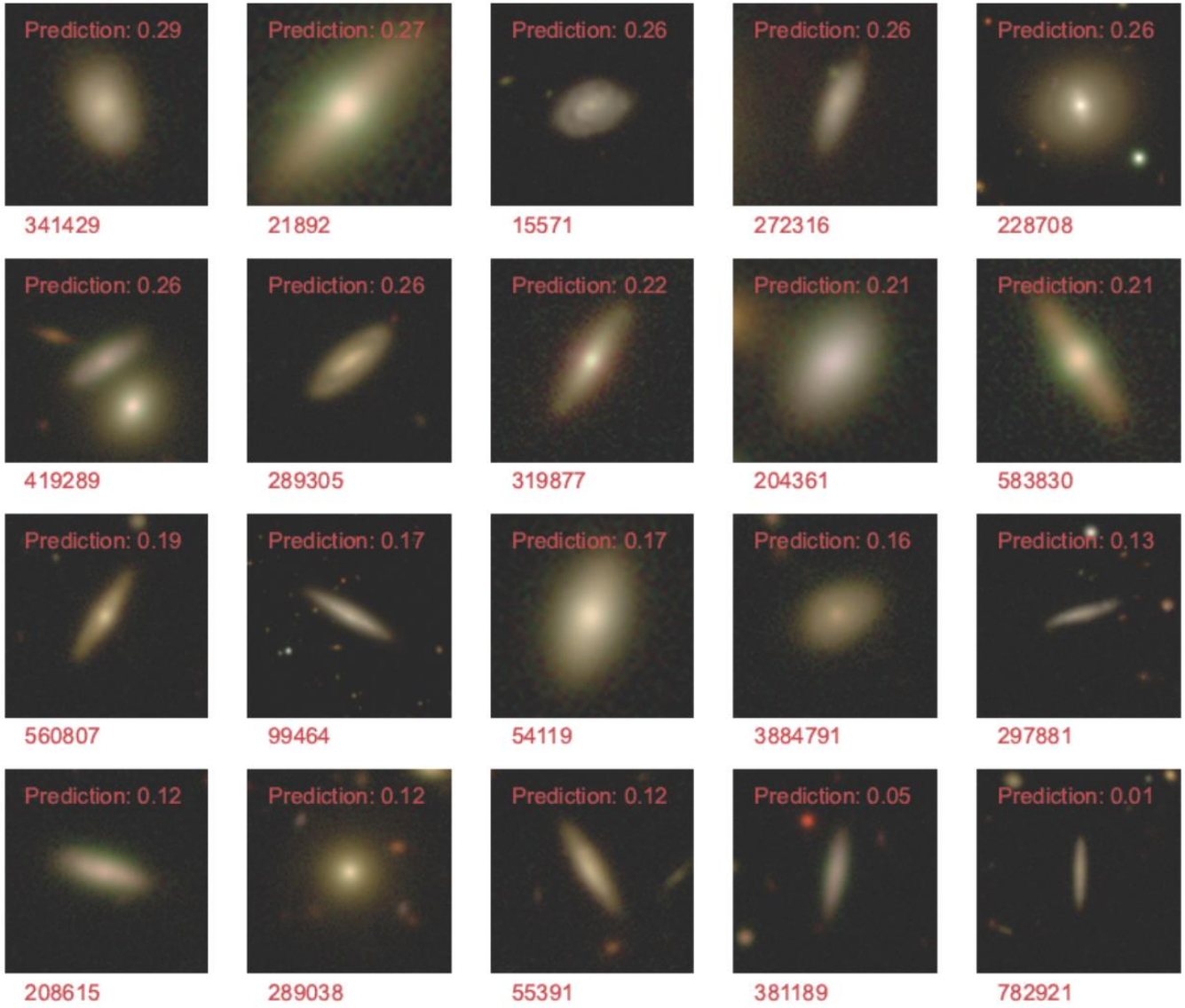
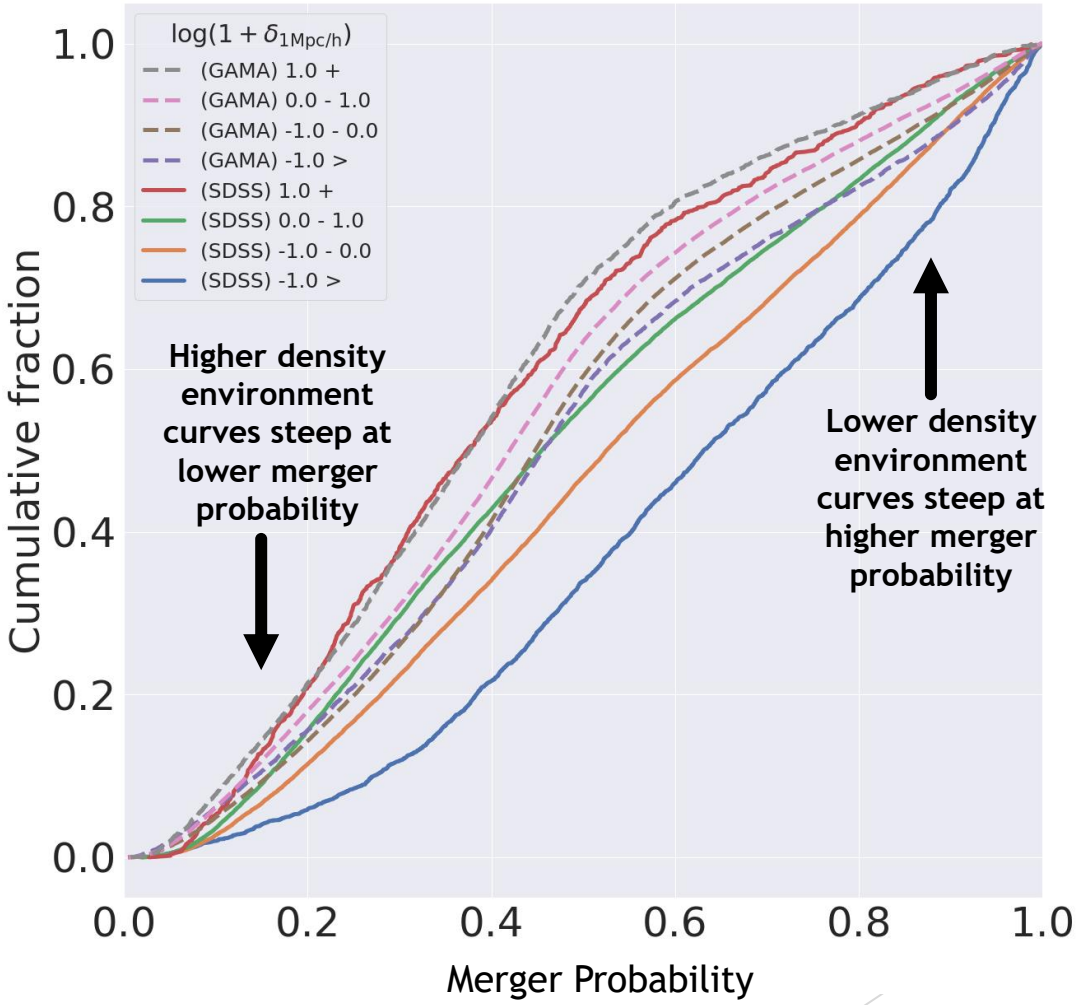


Galaxy Mergers and Environment

- We investigate the relationship between galaxy mergers and their environment - **where** do mergers occur?

Merger Probability Cumulative Fractions by Density in 1 Mpc radius



AGN Identification - PROSPECT

- Full SED Modelling done using SED fitting code PROSPECT (Robotham et al. 2021)
  - Modeling for **Galaxy** component and **AGN** component
  - Accounts for emissions over wide wavelength, accounts for dust torus emission

- AGN identification from Thorne et al. (2021)
  - Flux contribution fraction from AGN relative to whole galaxy SED - f_{AGN}
  - AGN –13,000 galaxies with $f_{\mathrm{AGN}} > 0.1$
    - Each AGN has a redshift/stellar mass/SFR matched non-AGN

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Galaxy Mergers and AGNs

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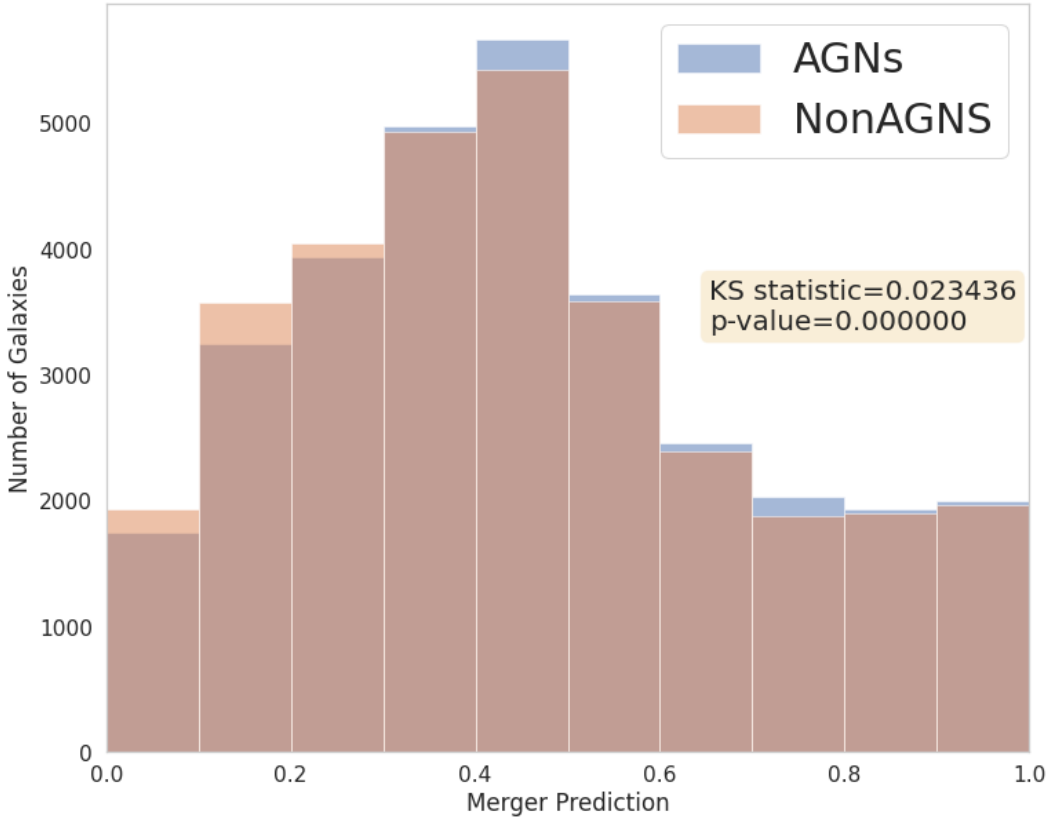

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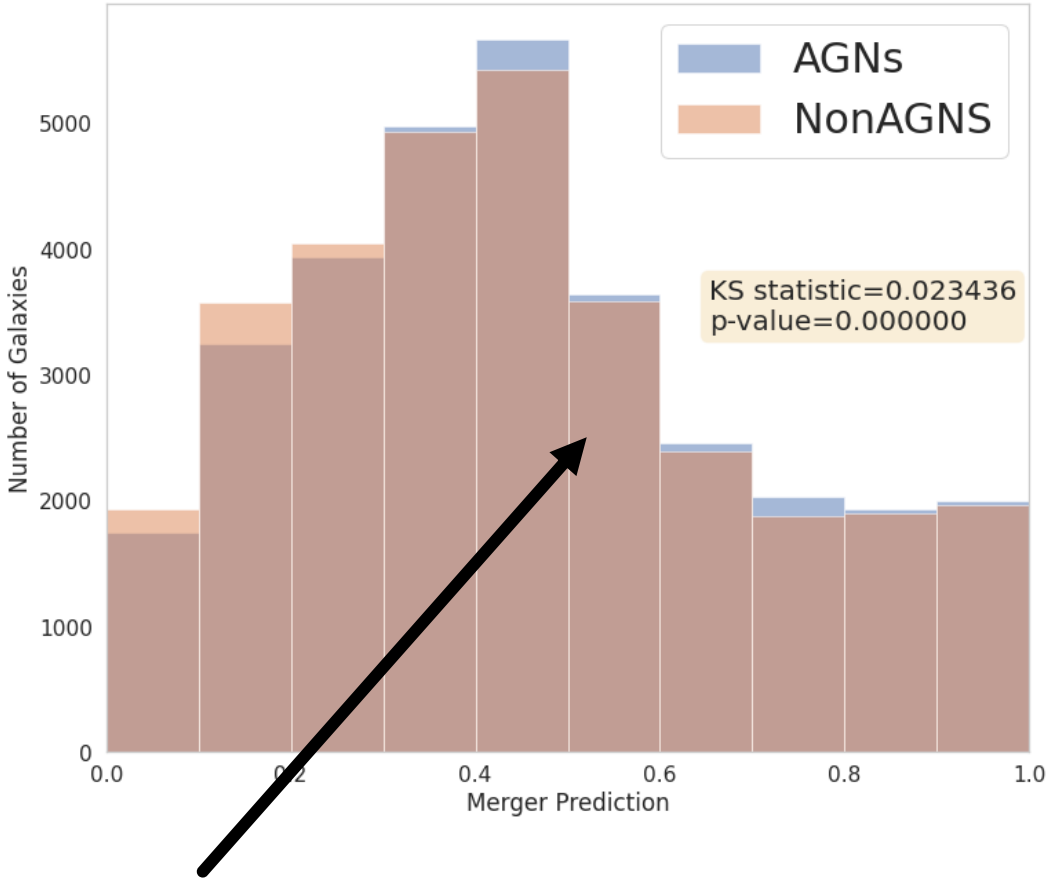

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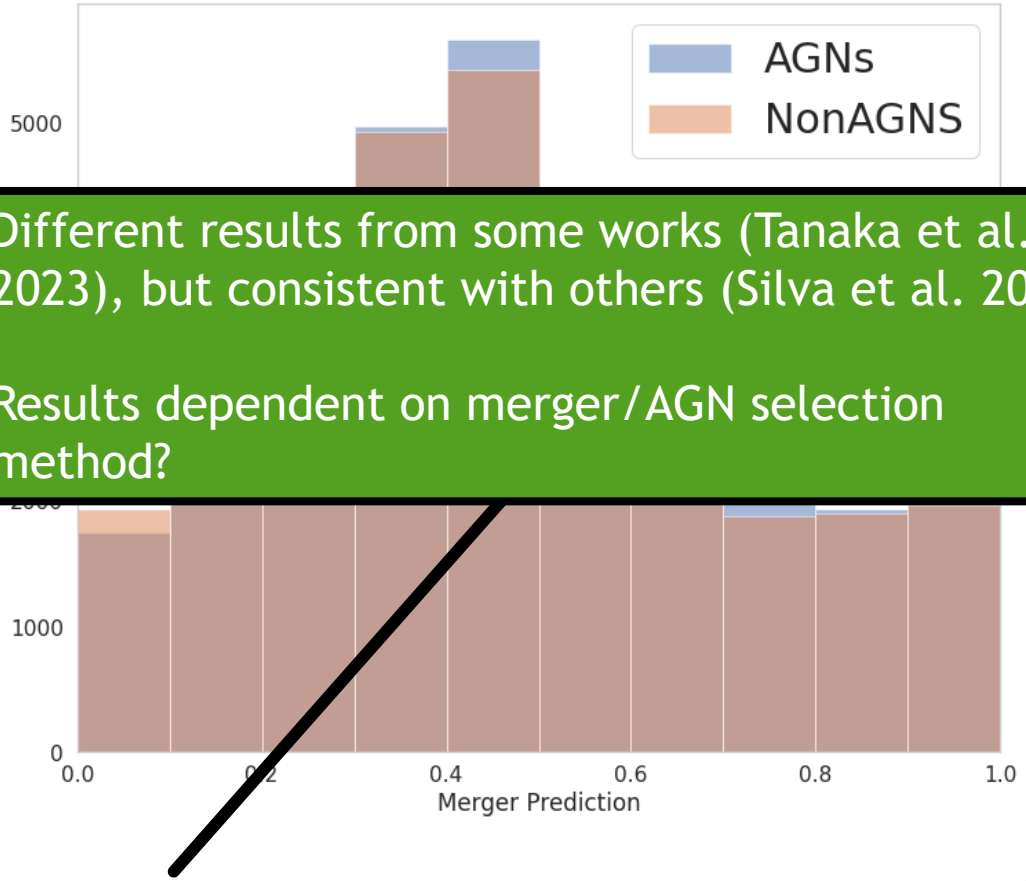


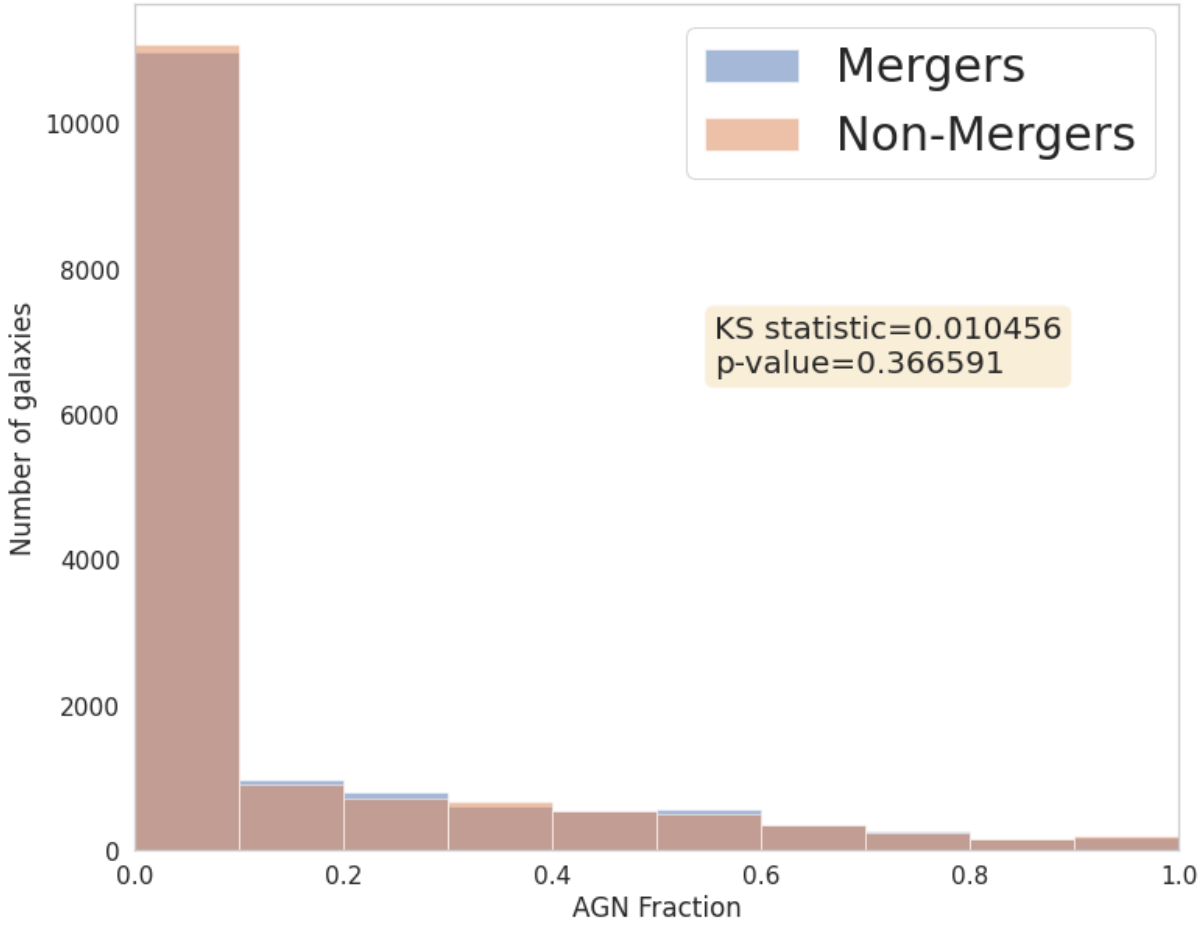
Different results from some works (Tanaka et al. 2023), but consistent with others (Silva et al. 2021)

Results dependent on merger/AGN selection method?

No distribution difference!

Galaxy Mergers and AGNs

- Reverse check – does the distribution of f_{AGN} change between mergers (merger probability > 0.8) and non-mergers? (merger probability < 0.3)



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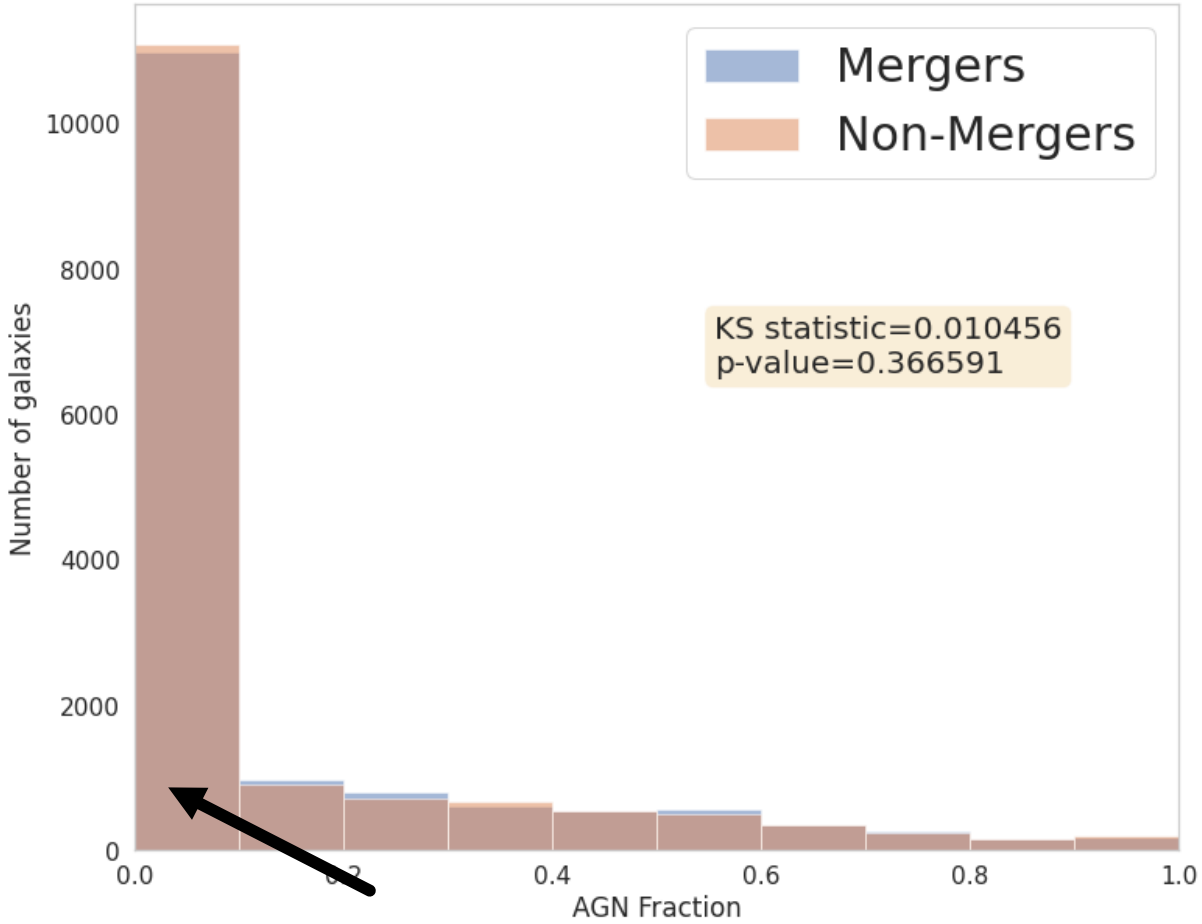
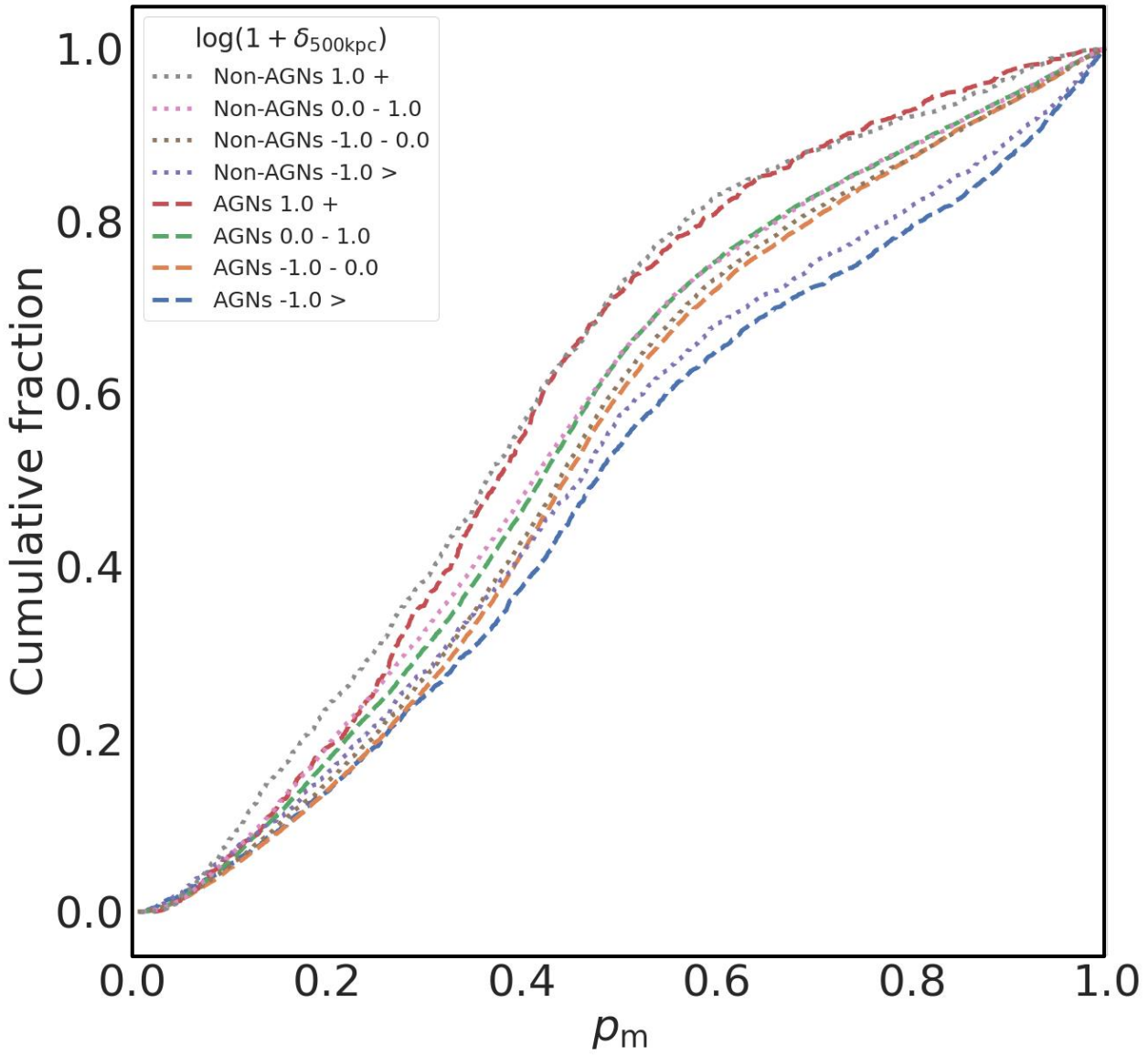


KS-test says different distribution, but peak still at low f_{AGN}

Galaxy Mergers and AGNs

- Is there a relation between **AGNs, mergers, and environment?**
- Cumulative merger probability distributions, binned by mass overdensities within a 500 kpc/h radius aperture (Yesuf et al. 2023) for AGN (dashed) and non-AGNs (dotted)
- Merger-environment relation consistent with Omori et al. (2023)
- AGN-environment little to no relation?
  - Overdensest regions have slightly more non-merger non-AGNs…



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Summary

- We made merger predictions on HSC-SSP-GAMA matched AGNs/non-AGNs
- We find **little difference** between
  - Merger probability distribution between AGNs/non-AGNs
  - f_{AGN} distribution between mergers/non-mergers
- Merger-Environment relation similar between AGN and non-AGN
- There are **more to AGNs than merger activity**