





Mergers and AGNs in the HSC-SSP: Do Mergers Trigger AGN Activity? Kiyoaki Christopher Omori (Nagoya University/JSPS DC2 Fellow)

November 21, 2023

初代星・初代銀河研究会2023

Results are preliminary!

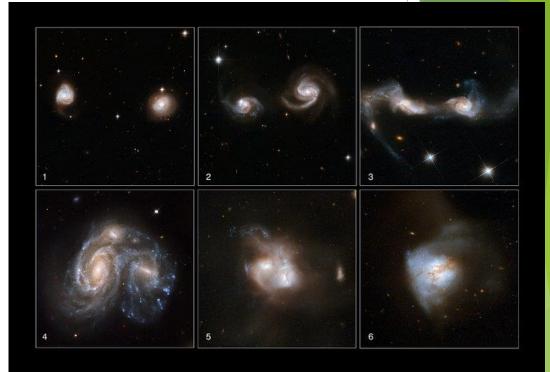
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Intro

- Sample Selection Method
- Results
- Summary

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)

Background - Galaxy Interactions

Galaxies evolve

 The commonly accepted pathway for structure growth is through
 hierarchical growth
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Galaxies interact/merge with other galaxies form a new galaxy (c) Interaction/"Merger"



 now within one halo, galaxies interact & lose angular momentum
 SFR starts to increase
 stellar winds dominate feedback
 rarely excite QSOs (only special orbits)

(b) "Small Group"



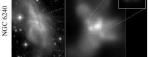
 halo accretes similar-mass companion(s)
 can occur over a wide mass range
 Mhalo still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



- halo & disk grow, most stars formed - secular growth builds bars & pseudobulges - "Seyfert" fueling (AGN with M_b >-23) - cannot redden to the red sequence

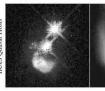
(d) Coalescence/(U)LIRG



- galaxies coalesce: violent relaxation in core - gas inflows to center: starburst & buried (X-ray) AGN - starburst dominates luminosity/feedback,

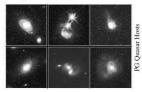
but, total stellar mass formed is small





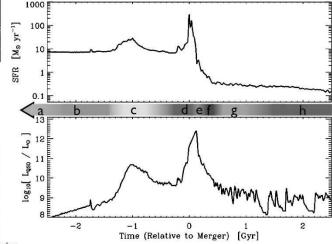
 BH grows rapidly: briefly dominates luminosity/feedback
 remaining dust/gas expelled
 get reddened (but not Type II) QSO: recent/ongoing SF in host high Eddington ratios merger signatures still visible

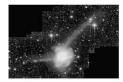
(f) Quasar



 dust removed: now a "traditional" QSO
 host morphology difficult to observe: tidal features fade rapidly
 characteristically blue/young spheroid

(g) Decay/K+A





 QSO luminosity fades rapidly

 tidal features visible only with very deep observations
 remnant reddens rapidly (E+A/K+A)
 "hot halo" from feedback
 sets up quasi-static cooling

(h) "Dead" Elliptical

 star formation terminated
 large BH/spheroid - efficient feedback
 halo grows to "large group" scales: mergers become inefficient
 growth by "dry" mergers

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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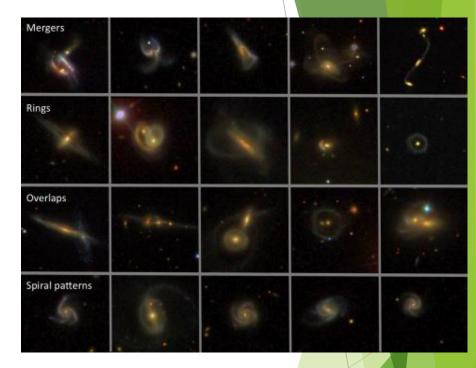
Sample Selection

- ~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

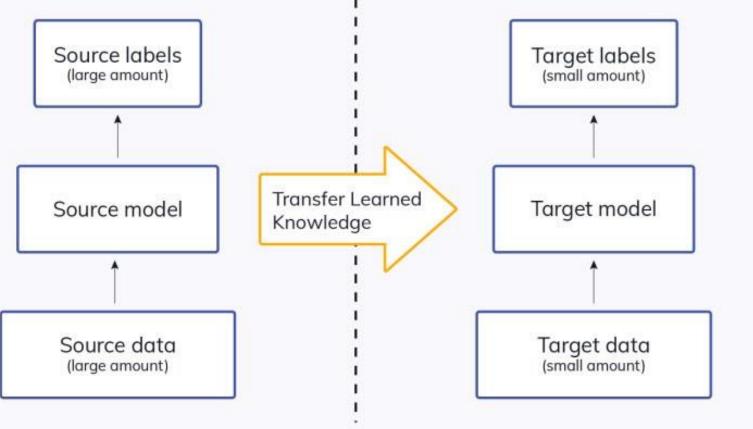
Interacting Galaxy Classification -Machine Learning

- 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-zooscoming-soon-to-a-space-telescope-near-your-planet/

Transfer Learning

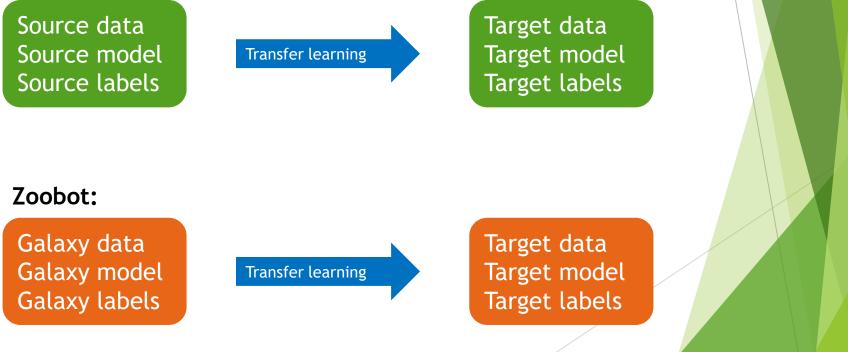


- https://www.v7labs.com/blog/transfer-learning-guide
- Re-using a pre-trained model as a starting point for a new task
 - Examples: ImageNet, AlexNet
- Transfer learning for merger classification has been used in galaxy studies (Ackerman et al. 2018)

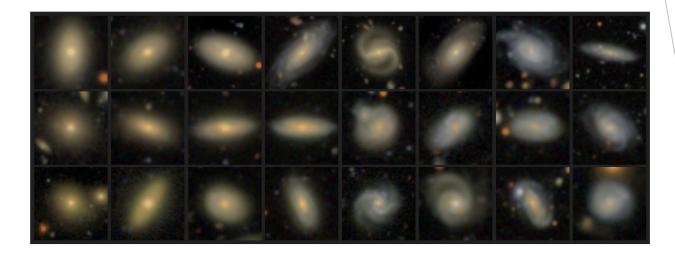
Merger Probabilities- Zoobot (Walmsley et al. 2022) trained model (Omori et al. 2023)

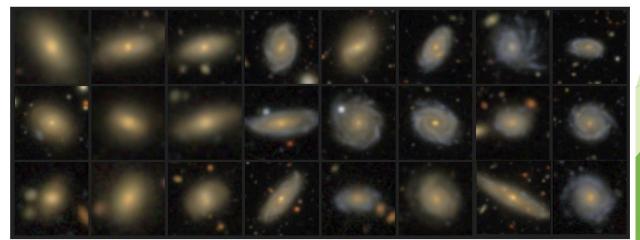
- Network pre-trained on Galaxy Zoo DECaLS images and their 96 million clicks
- General transfer learning improves classification accuracies (Ackerman et al. 2018), fine-tuning models pre-trained on galaxy images can further improve accuracies





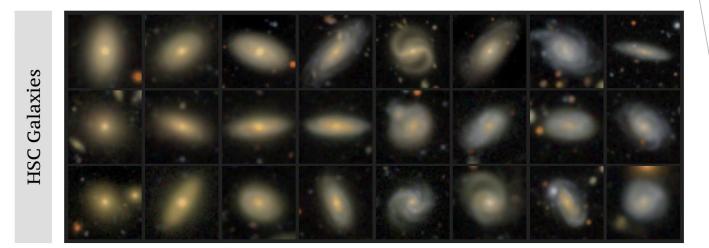
- Model fine-tuned with "ground truth" images
 - Simulation mock images that are "observation-ised"
 - Illustris TNG50 mock images that are "HSC-ized"





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

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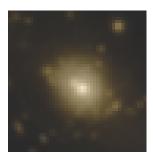


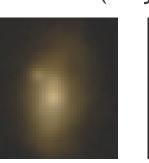


Credit: Rhythm Shimakawa -NAOJ, Bottrell+ (2023)

We fine-tune the Zoobot model using Illustris TNG50 mergers and non-mergers

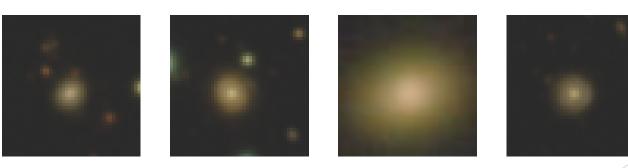
Mergers: < 0.5 Gyr since/until closest merger event (major/minor/mini mergers)







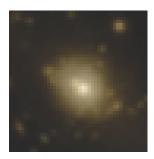
Non-mergers: > 3 Gyr since/until closest merger event

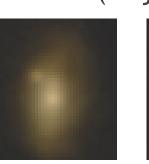


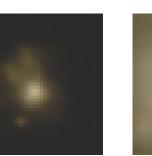
291 galaxies x 4 viewing angles = 1164 fine tuning samples per class

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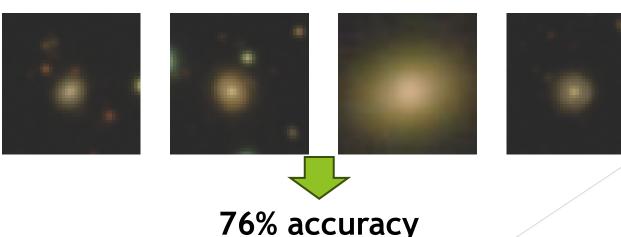






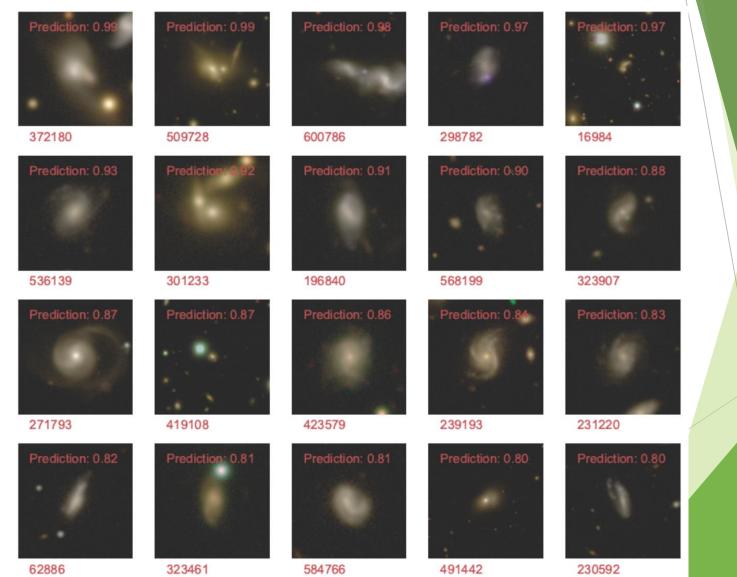
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Results - Classification

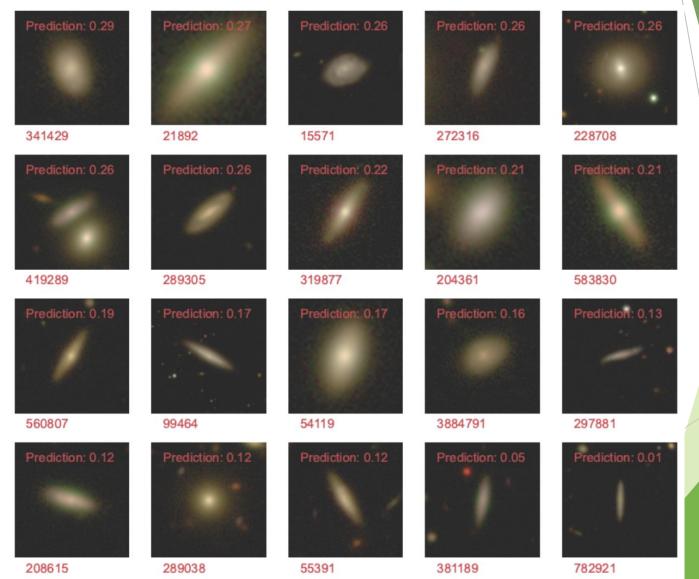
We have applied our model and made predictions for ~300,000 HSC S21A images - merger examples



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Results - Classification

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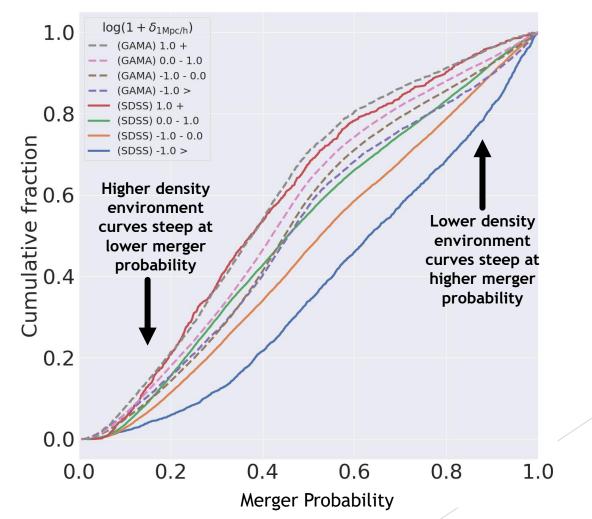


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Galaxy Mergers and Environment

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)

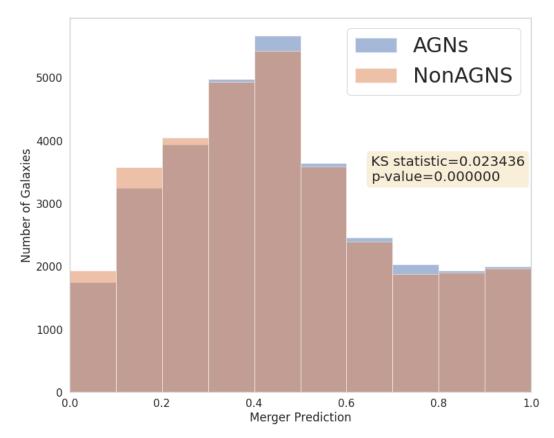
- Flux contribution fraction from AGN relative to whole galaxy SED f_{AGN}
- ► AGN -13,000 galaxies with $f_{AGN} > 0.1$
 - Each AGN has a redshift/stellar mass/SFR matched non-AGN

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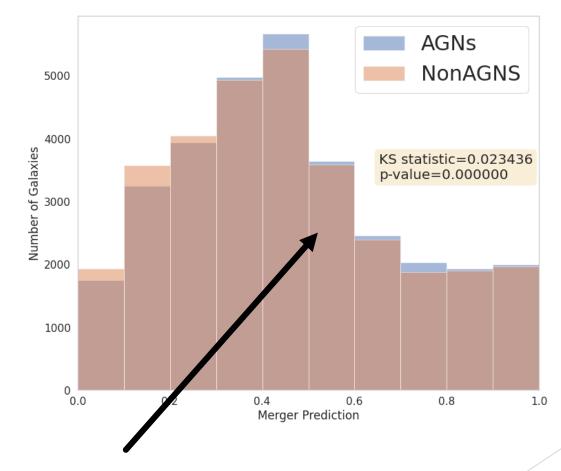
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We investigate the relationship between galaxy mergers and AGNs - is the merger probability enhanced in AGNs? (f_{AGN} > 0.1)

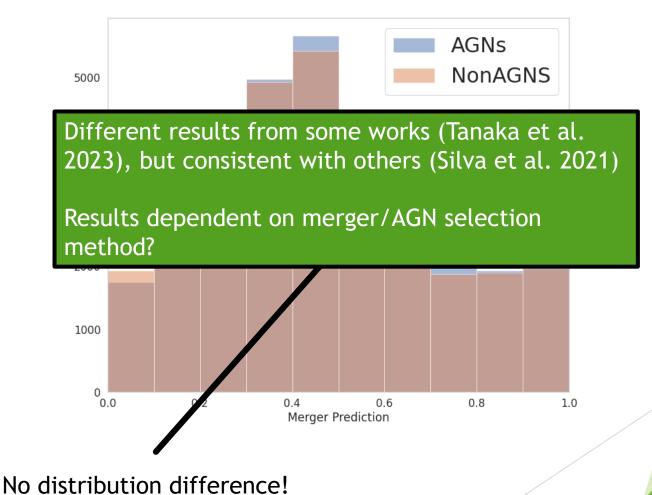


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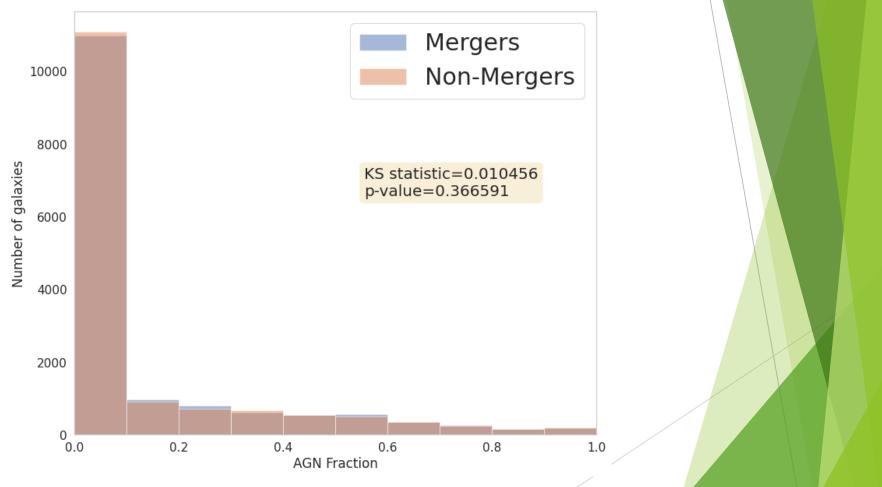


No distribution difference!

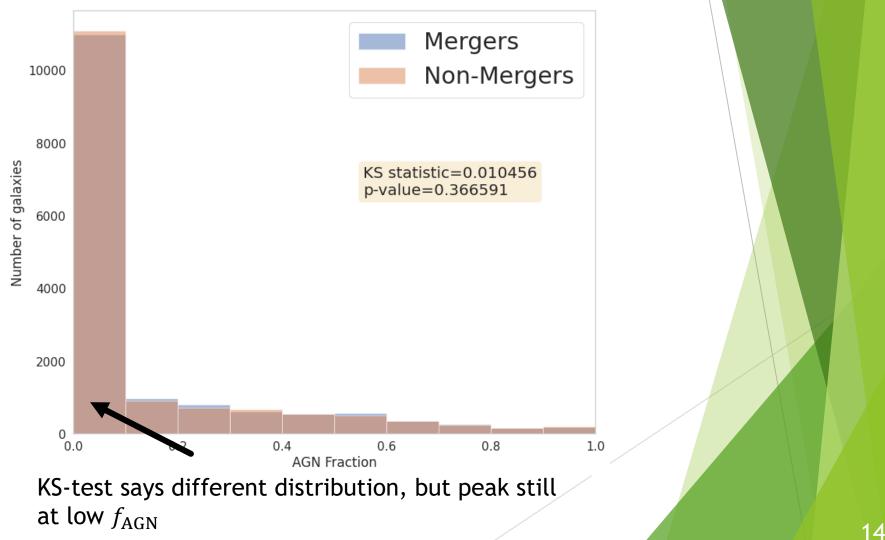
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Reverse check - does the distribution of f_{AGN} change between mergers (merger probability > 0.8) and nonmergers? (merger probability < 0.3)



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



- 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...

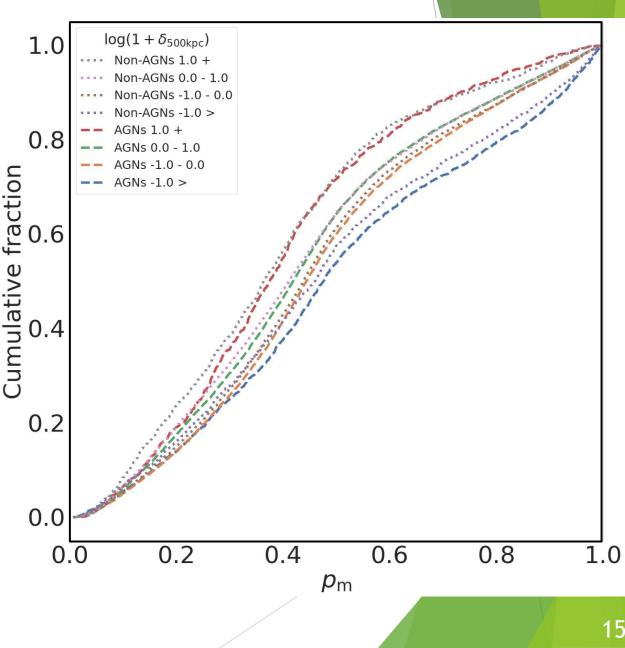


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- We made merger predictions on HSC-SSP-GAMA matched AGNs/non-AGNs
- We find little difference between
 - Merger probability distribution between AGNs/non-AGNs
 - *f*_{AGN} distribution between mergers/nonmergers
- Merger-Environment relation similar between AGN and non-AGN

There are more to AGNs than merger activity