

# Census of Dual & Group AGNs in DESI DR1 as Precursors to SMBHs

Zoë Painter, Ekaterine Dadiani, Antonella Palmese  
Carnegie Mellon University

## Abstract

Presented here is a census of dual and offset active galactic nuclei (AGNs) as well as larger AGN groups using spectroscopic data from the Dark Energy Spectroscopic Instrument's (DESI) first data release (DR1). From the ~17,000 sources, galaxies and quasars pairs with  $\Delta r \leq 50$  kpc have been identified. AGN identification was done using the AGN/Galaxy Classification Value-Added Catalog (VAC). The current sample contains over 7,000 dual AGN candidates and over 27,000 offset AGN candidates over  $0 \leq z \leq 3.6$ . DESI notably expands the current population of dual AGN candidates. This sample also contains 25 triplet AGN groups. Of these, 64% have all members  $\Delta r \leq 50$  kpc. This sample contains over 250 groups with a minimum of 2 AGNs. 17% of these groups are found at  $z \leq 0.01$ . These catalogs are not complete and require minor additional cleaning. This project aims to be expanded by using DESI's second data release (DR2). DR2 contains approximately 3 times the sources of DR1. Due to the increased volume of objects, a machine learning tool is intended to be created to ease the visual inspection process for pairs. The final goal is to establish a wide-area census of kpc-scale dual AGNs in DR2 and link these findings to massive black hole mergers.

## Background

### DESI

The Dark Energy Spectroscopic Instrument (DESI) is a robotic, fiber-filled spectroscopic survey. Its main survey began in May 2021 and aims to collect spectra for ~63 million objects.



(Images - KPNO)

### Supermassive Black Holes & Active Galactic Nuclei

- Galactic merges are believed to be the driving cause behind the formation of supermassive black holes (SMBHs),
- The gravitational torque caused by mergers sends massive amounts of gas to the galactic center.
- This gas fuels rapid accretion and ignites active galactic nuclei (AGNs).
- The gas-rich phase of galactic mergers is a critical observational timeframes as both galaxies contain SMBHs that are actively accreting and therefore appear as dual AGNs.

### Current Research Goal

Create a census of dual AGNs and groups containing 2 or more AGNs in DESI's data release 1 as a precursors to mergers of supermassive black holes and collect interesting cases throughout the census.

## Methodology

### DR1 & AGN Catalog

- The data is from DESI DR1, representing the first 13 months of the main survey.
- For AGN identification, AGN/Galaxy Classification Value-Added Catalog (VAC) was used.
- This data, in junction with the VAC, provides spectral data, AGN identification tags, and other galactic properties.

### Pair Finding

- Galaxies were clean based on  $\text{SNR} \geq 5$  and  $\text{Chi}^2 \leq 10$  prior to pairing.
- All combination in one healpix were checked to find pairs with  $\Delta r \leq 50$  kpc.
- The edges of healpix were then checked.
- All pairs were then clean based on  $\Delta v \leq 600$  km/s and  $\Delta r \geq 0.5''$ .

### Group Finding

- A network graph was created using the pair data as an input,
- As objects were identified as groups, they were removed from the pairs catalog.
- Groups were then separated into pure AGN groups and minimum 2 AGN groups.

## Visual Inspection

- DESI will often have multiple observations for the same object due to its fiber size of  $1.6''$ .
- This means many pairs and groups had to be visually inspected including:
  - Pairs with  $\Delta r \leq 2''$
  - All pure AGN groups
  - All min. 2 AGN groups

### Future Cleaning

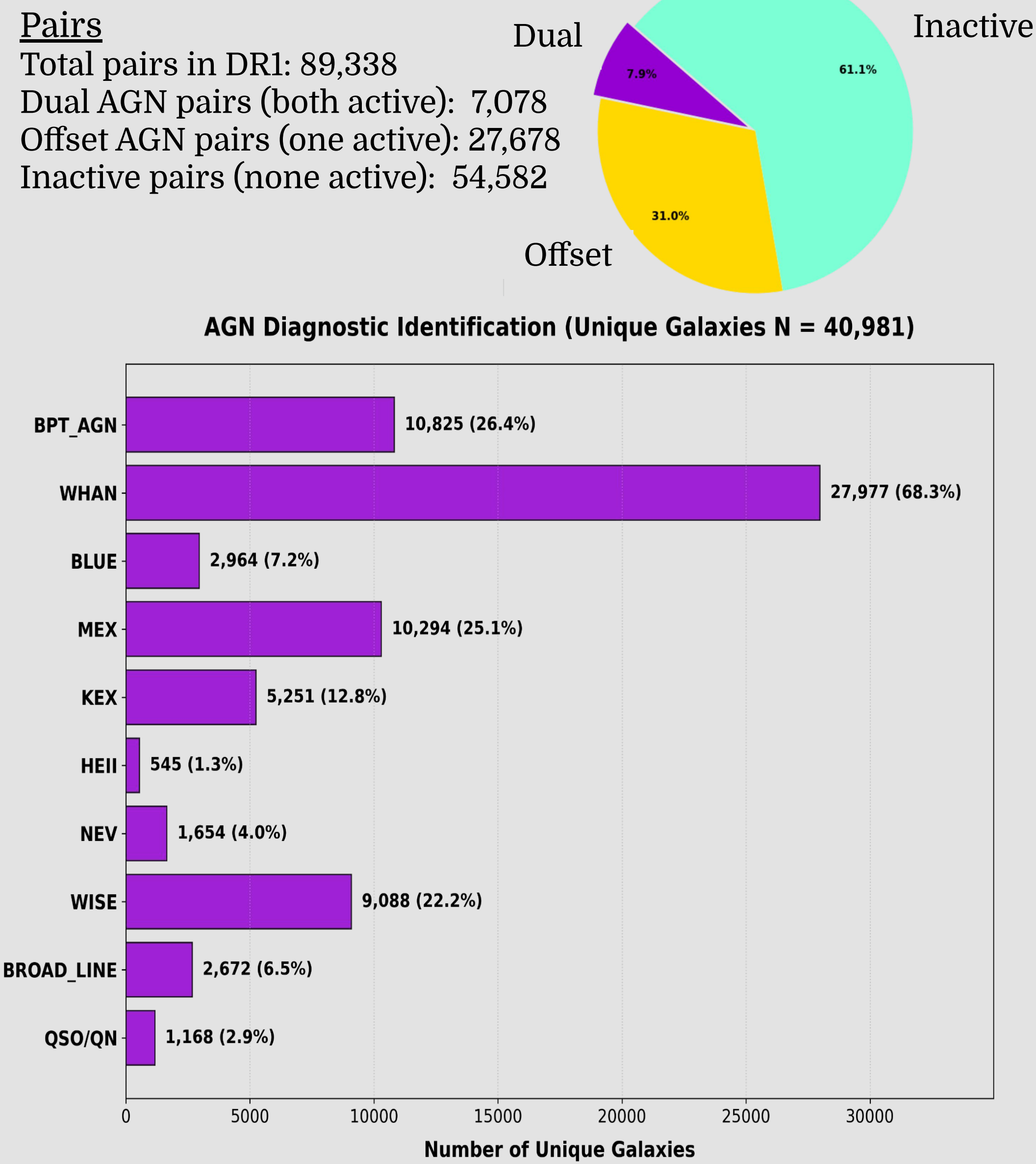
- False pairs will be used to remove duplicates in the pair catalog.
- False prue AGN groups will be sorted into pairs and min. 2 AGN groups.
- False min. 2 groups will have false members removed and sorted into other groups.

## Results

These results are not final. Another round of cleaning will occur for some data sets.

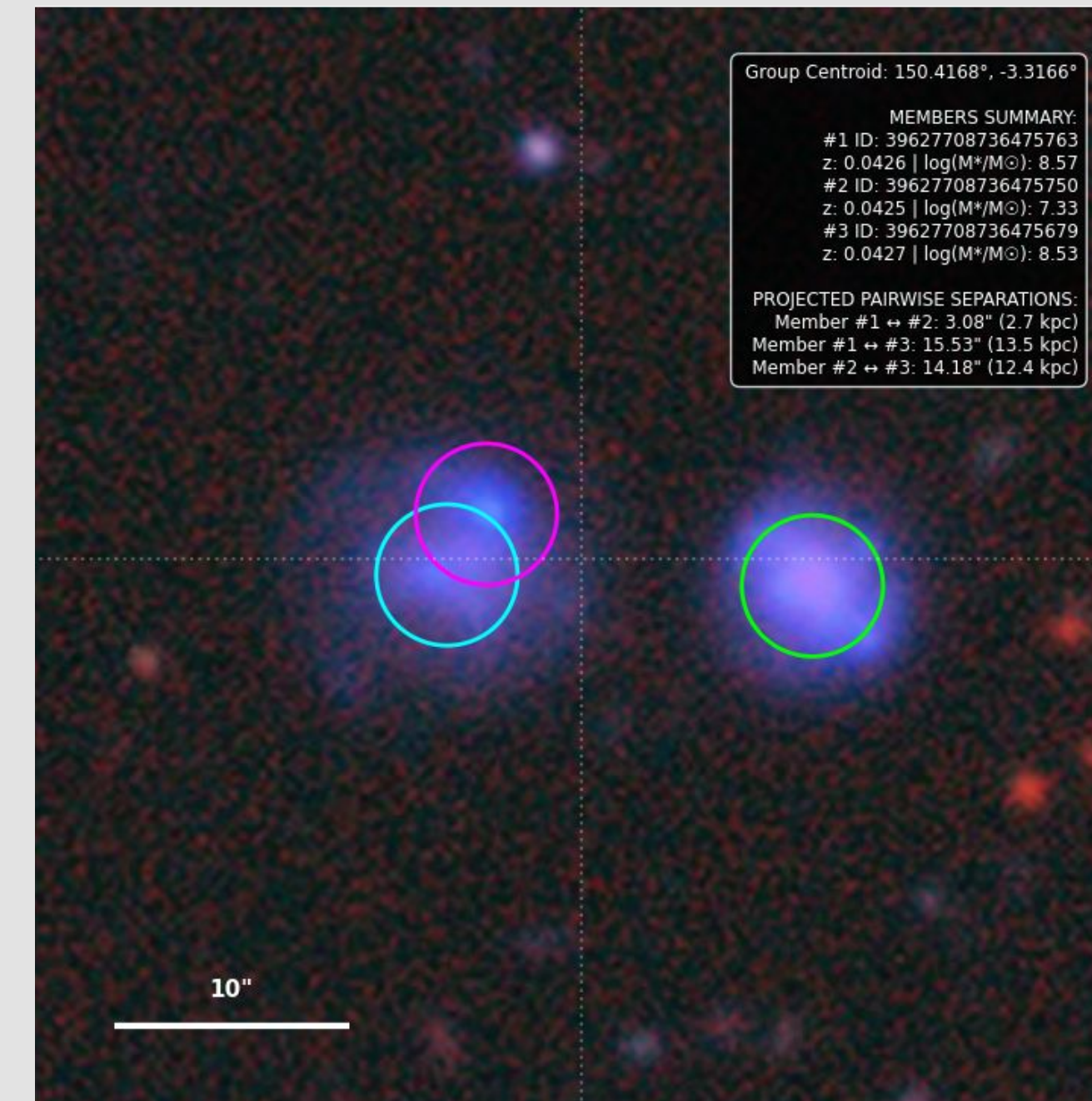
### Pairs

Total pairs in DR1: 89,338  
Dual AGN pairs (both active): 7,078  
Offset AGN pairs (one active): 27,678  
Inactive pairs (none active): 54,582



### Groups

Pure AGN Groups: 25 all Triplets  
Minimum 2 AGN Groups 269



### Pure AGN Case Study

This group is interesting due to two of its unique characteristics

- Compact: all members are less than 15 kpc in separation.
- Low Mass: all members have a  $\text{Log}(M) \leq 9$ .

### Minimum 2 AGN Groups

- Of the 269 groups in this catalog, 47 sit at a redshift less than 0.01.
- Many of these groups contain over 10 galaxies.
- These groups will require another round of cleaning to remove duplicate members.

## Conclusions

While these catalogs do require another round of cleaning, many interesting conclusions can be drawn.

Out of the approximately 90,00 pairs identified over 7,000 of them have been identified as dual AGN candidates, increasing the know population.

Pure AGN Triplets are notably rare. We have identified 25 candidates for AGN triplets.

The 269 minimum 2 AGN groups provide examples of large system. They also allow for potential investigation into AGN activation in the creation of pure AGN systems

## Next Steps

This project is intend to continue in the next academic year. These next steps will continue the goal of build a complete census of dual AGN and group AGN candidates as well as continue into new data sets.

### Continuation of Cleaning & Analysis

- All three current catalogs require continued cleaning.
- Rejected pairs will be used to identify better observations between duplicate objects. The pairs containing the cleaner observations will be retained while the other will be removed.
- Both rejected pure AGN groups and min. 2 AGN groups will be cleaned to identify pairs and groups falling into the other category.

### DESI DR2

- DESI's second data release became available in March of 2026.
- This data contain all objects found in DR1 in addition to new observations.
- DR2 contains approximately 3 times the number of observations in DR1.
- Once the AGN/Galaxy Classification Value-Added Catalog is available for DR2, this project will transition to that data set.

### Visual Inspection Machine Learning Tool

- Visual Inspection serves as a bottleneck in the cleaning process.
- With the additional volume of DR2, this step will only increase in time.
- The goal is to train a machine learning tool to perform the visual inspection.
- This tool would focus on the pair catalog and not the group. The volume of pairs that require visual inspection is much larger than that of either of the group catalogs. The groups also add an additional level of difficulty that can create more room for error for the tool

## References

Images - KPNO. (n.d.-a). <https://kpno.noirlab.edu/images/>  
Di Matteo, T., Springel, V., & Hernquist, L. 2005a, Nature, 2548 433, 604, doi: 10.1038/nature03335  
Adi Foord et al 2021 ApJ 907 71

## Acknowledgements

| Project Advisor: Dr. Antonella Palmese  
| Graduate Advisor: Ekaterine Dadiani  
| Dr. Hy Trac  
| CMU Summer Scholars Program