The Incidence of Active Galactic Nuclei in Galaxy Groups

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Introduction

Ongoing research indicates a correlation between the properties of AGNs and the properties of their host galaxies. AGNs, or Active Galactic Nuclei, are caused by accreting black holes in the centers of galaxies (Cappelluti et al., 2010). They influence properties of these galaxies such as stellar mass, star formation rate, and color (Coil et al., 2009; Hickox et al., 2009). In order to better understand the mechanisms for AGNs and the evolution of galaxies containing AGNs, it is important to study the clustering nature and environments of these host galaxies. Our study of AGN behavior uses data from the Bootes survey. Bootes, one of the widest continuous field X-ray surveys ever constructed, uses the spatial resolution of the Chandra X-ray telescope to detect 3,293 X-ray sources across its 9 square degree field (Murray et al., 2005).

In this project we aim to constrain the environments of AGNs observed in the Bootes field using the optical AGN and Galaxy Evolution Survey (AGES) catalog. AGES is a redshift survey in the Bootes field that uses the 6.5m MMT telescope (Kochanek et al., 2011, in prep). We work to determine whether AGNs occur most frequently in groups of galaxies found between redshifts 0.01 and 0.8. This fits in with ongoing research to constrain the properties of AGNs.

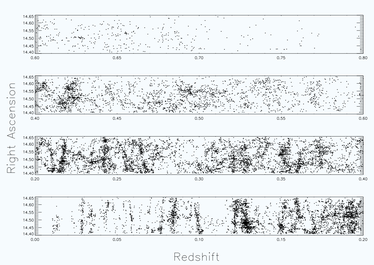

Figure 1: Cone plot of all extended sources in the entire Bootes field. Here we plot Right Ascension against Redshift. Using this we can qualitatively look at "clumps" in the field. Notice the areas of greater density visible in the area z < 0.8 that may indicate the presence of galaxies in groups.

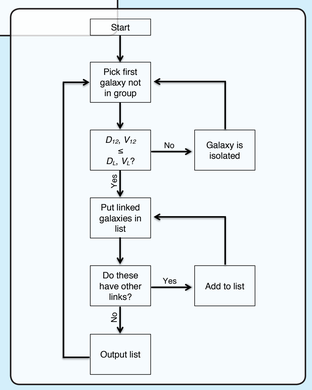

Figure 2: An explanation of the method used to construct the group finding algorithm. The algorithm was designed to loop over each individual galaxy in the list and determine whether it had neighbors. We then placed each galaxy and its neighbors in a column of an array. The program then through the intersection of sets combined the columns with galaxies in common, thus outputting groups with no overlap. This process was repeated for every column.

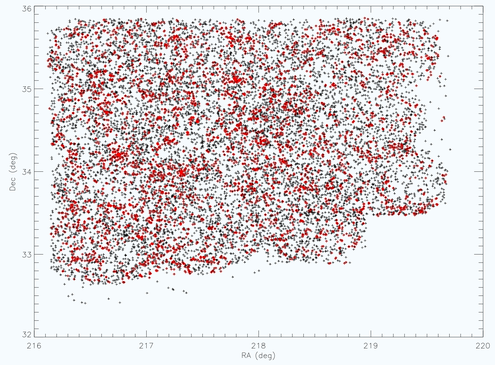

Figure 3: The result of the Friends-of-Friends algorithm showing all the galaxies in the AGES catalog with sources in groups overplotted in red.

Methods

- We produce a Friends-of-Friends algorithm (Geller & Huchra, 1983) that finds groups of extended sources linked by distance and velocity in the redshift range 0.01 < z < 6.0 (Fig 2, 3). We find 4,758 of ~15,000 extended sources to be in groups with 505 groups that have more than 2 galaxies.
- We use a great circle calculation to determine which optical sources "match" our AGN. We use a minimum radius of 2.2 arcseconds and discard all X-ray sources with fewer than 4 counts to increase accuracy. This produces 1,505 corresponding X-ray sources, or ~50% of the restricted catalog.
- Comparing the results of the matching program to the results of the Friends-of-Friends algorithm, we determine whether any objects in groups are AGN.

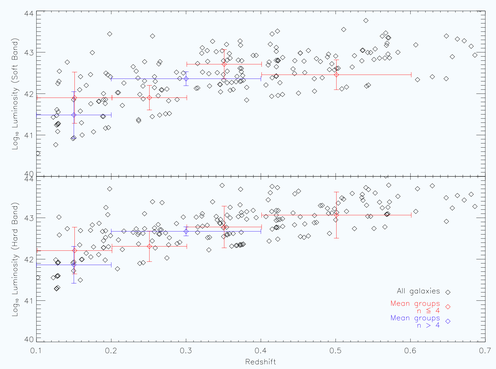

Figure 4: Log luminosity of X-ray source galaxies in both soft and hard bands plotted against redshift. Log mean luminosities for groups of 2-4 galaxies and groups of more than 4 galaxies are overplotted. There is little difference in the luminosities in either band for X-ray sources in large or small groups.

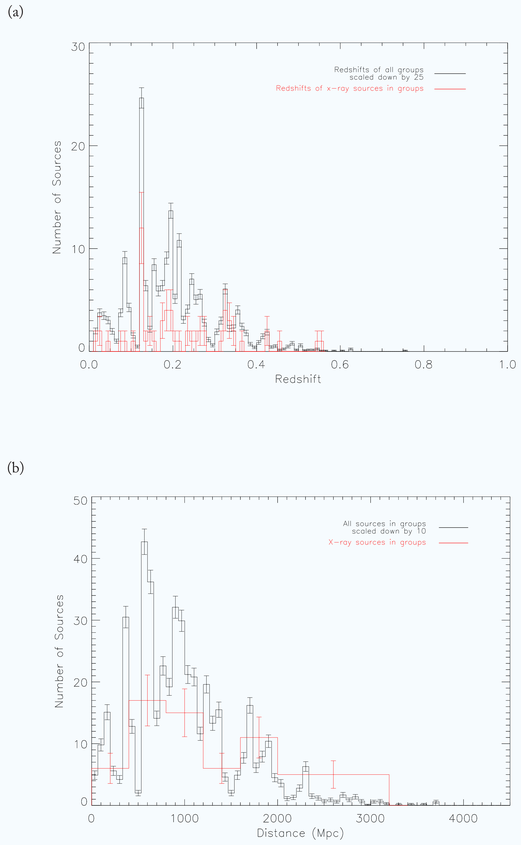

Figure 5: Redshift distribution of sources in groups, scaled down by a factor of 25 for ease of comparison with overplotted AGN in groups in red (a). The redshift distribution of AGN in groups nearly exactly duplicates the distribution of all group sources in the AGES catalog.

In (b) we plot the distribution of the distances of sources in groups scaled down by a factor of 10, once again for ease of comparison. The distances of AGN in groups are overplotted in red. Despite the larger bin size it is clear that these distributions are also consistent with one another, although the optical distribution has a relatively larger peak at ~700 Mpc.

The graph (c) shows the distribution of apparent magnitude for sources in groups scaled down by a factor of 25. We show our limiting magnitude cutoff and overplot the apparent magnitudes of AGN in groups in red. The distribution here does not follow that of all group sources in the AGES catalog with no defined peak at 18 < m < 20.

Conclusion

We determined 215 of the matched X-ray sources to be galaxies with 49 sources in groups with redshift 0.01 < z < 0.6. No X-ray sources were found in groups at redshift z > 0.6. We found that the redshifts (Fig. 5a) and distances (Fig. 5b) of these matched X-ray sources were consistent with their optical counterparts, both in groups and overall. We found that the distribution of apparent magnitude for X-ray sources was similar to the optical sources, but showed X-ray sources to be consistently fainter than the optical (Fig. 5c). It is unlikely for the X-ray magnitude distribution to differ from its optical counterpart.

We found 24 of 49 group X-ray sources to be in large groups of greater than 4 galaxies which occurred at redshifts 0.01 < z < 0.4. The remainder of the X-ray sources in groups were found in groups of 4 or fewer galaxies at 0.01 < z < 0.6. Groups of both sizes were found with consistent mean luminosities of ~1.8×10^{42} erg/s in the soft band and ~8.5×10^{41} erg/s in the hard band (Fig. 4). Over all, AGN in groups showed no significant differences in their physical properties. We found that we currently lack the source statistics to constrain physical trends in the data.

Acknowledgements

I would like to thank the Summer Undergraduate Research Fellowship program, and Dr. Christine Jones and Dr. Andy Goulding for the opportunity to work on this project. I also thank the Smithsonian Astrophysical Observatory for providing facilities for this research, Professor Fiona Harrison for her support, Dr. Jan Vrtilek for his guidance, and Dr. Margaret Geller for walking me through the original friends-of-friends algorithm. Thank you to the SURF office at Caltech and the SAO Chandra team for their financial support.

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