Large Scale Environments of Nearby AGN

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Abstract
The properties of galaxies depend on their environmental density. Since the growth of black holes in active galactic nuclei may be an important phase in the evolution of all massive galaxies, the environments of these objects provide us information about the evolutionary processes leading to different types of AGN. We have studied the environments of z<0.4 AGN in the luminosity density field of galaxies. Our main results are that quasars, BL Lac objects and Seyfert galaxies are usually in low-density environments, while radio galaxies have higher environmental densities.

Introduction
The growth of supermassive black holes in active galactic nuclei (AGN) may be an important phase in the evolution of all massive galaxies. Through the morphology-density relation (Dressler, 1980, ApJ 236, 351) we know that the properties of galaxies depend on their large-scale environment. Because of this the large-scale environments of AGN may help us understand more about their evolution. The environment could tell us why galaxies become active or what is their phase in the activity cycle. It also provides information on differences between the different types of AGN. It has been suggested that different AGN are actually identical objects viewed from different directions (Antonucci 1993, ARA&A 31, 473). This would mean that they all have evolved the same way and in similar environments. Any differences between the environments of different kinds of objects would indicate differences in the evolution leading to the activity.

In Lietzen et al. (2009 A&A, 501, 145) we studied the environments of quasars using the fifth data release of Sloan Digital Sky Survey (SDSS). We found that quasars were located in low-density regions, at the edges of superclusters. We are now continuing this project by using luminous red galaxies (LRGs) in the seventh data release of SDSS, and we have added also other types of AGN in our study.

Methods
Our method is to use the galaxy catalog to create a luminosity-density field. LRGs follow the structure of cosmic web (the supercluster-void network) so that they are mostly located in the densest areas. This makes them reliable indicators of the structure. The high intrinsic luminosity of the LRGs allows us to study deeper and larger volumes. In Lietzen et al. (2009) we used normal galaxies, and our sample reached 500 Mpc distance, which contained 174 quasars. With LRGs we can now build a density field that reaches 1000 Mpc distance and contains over 2500 quasars.

A luminosity-density field is constructed by calculating the luminosity in each grid point in a cartesian grid, so that each galaxy contributes its luminosity. The field is smoothed using the B3-spline smoothing kernel to scale characteristic to superclusters. We use a 3 Mpc grid and 16 Mpc smoothing kernel for our LRG luminosity-density field (Fig. 1).

Results
Our AGN samples include BL Lac objects, quasars, Seyfert 1 and Seyfert 2 galaxies, and radio galaxies divided into steep and flat-spectrum sources. We calculated the average density of the grid points nearest to the targets in the luminosity-density field. Table 1 shows the details of our samples and the resulting averages of all targets. The distributions of density values are shown in Fig. 2. The results show that radio galaxies are located in higher density regions than other types of AGN. While almost half of other AGN are at regions of less than mean density of the whole density field (void areas), radio galaxies are more likely to be found in superclusters. This indicates that radio galaxies may differ from other AGN physically or through interaction with the intergalactic medium, instead of being only viewed from a different angle.

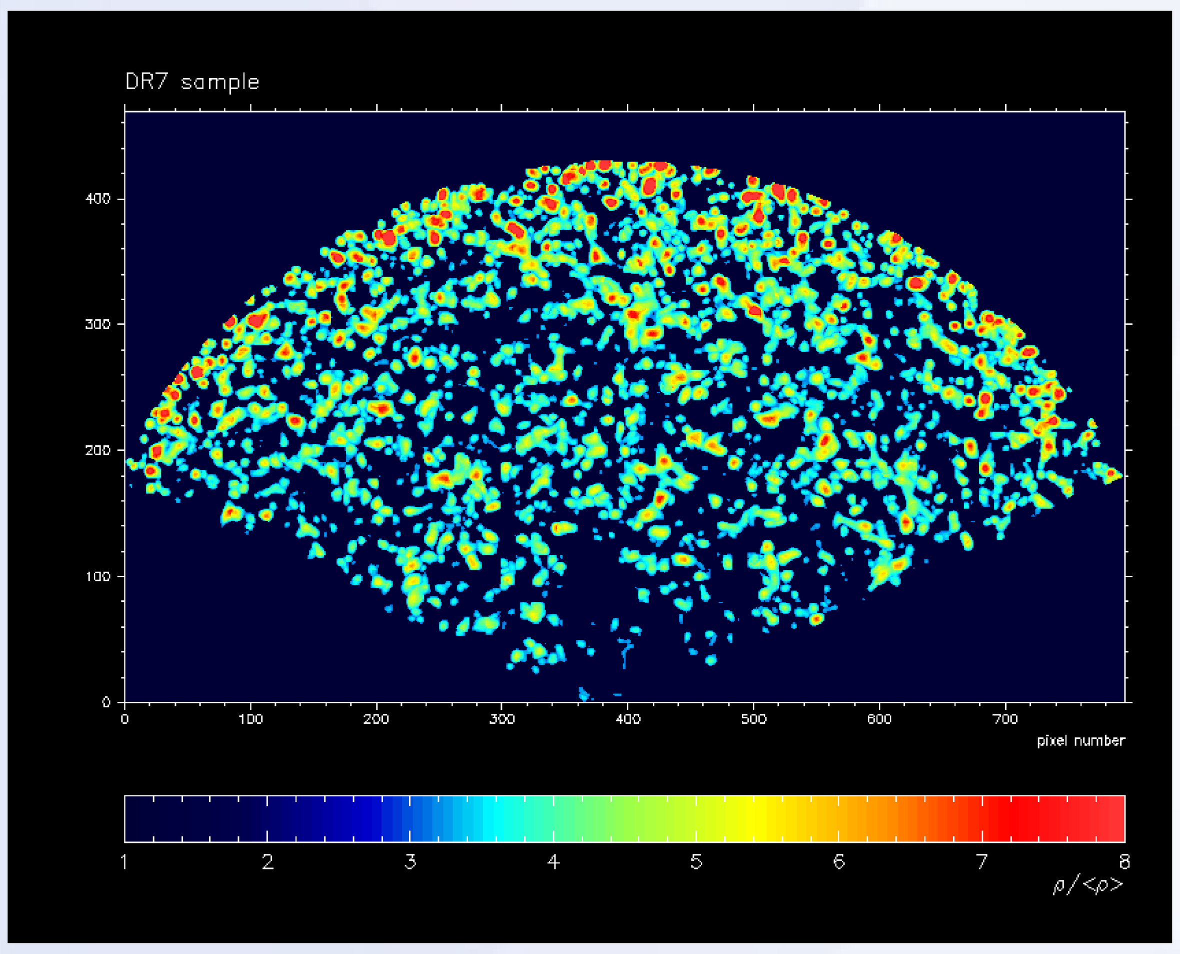

Figure 1
Luminosity-density field. Red areas represent the densest cores of superclusters, while dark blue areas are voids with very few galaxies.

Type	Source	Number of objects	Average density
BL Lac	Plotkin et al. 2010, ApJ 139, 390	91	2.18
Quasar	Schneider et al. 2010, 139,2360	3542	1.60
Seyfert 1	Veron-Cetty & Veron 2010, A&A	6580	1.61
Seyfert 2	Veron-Cetty & Veron 2010, A&A	2486	1.62
Steep radio galaxy	Kimball & Ivezić 2008, ApJ 136, 684	1019	2.64
Flat radio galaxy	Kimball & Ivezić 2008, ApJ 136, 684	710	2.37

Table 1
Samples of AGN in our work. Column 2 shows the catalog we have used, column 3 gives the number of objects in our sample, and column 4 shows our result for the average density of the environment (density points < 3 Mpc from the objects) in terms of mean densities of the whole density field.

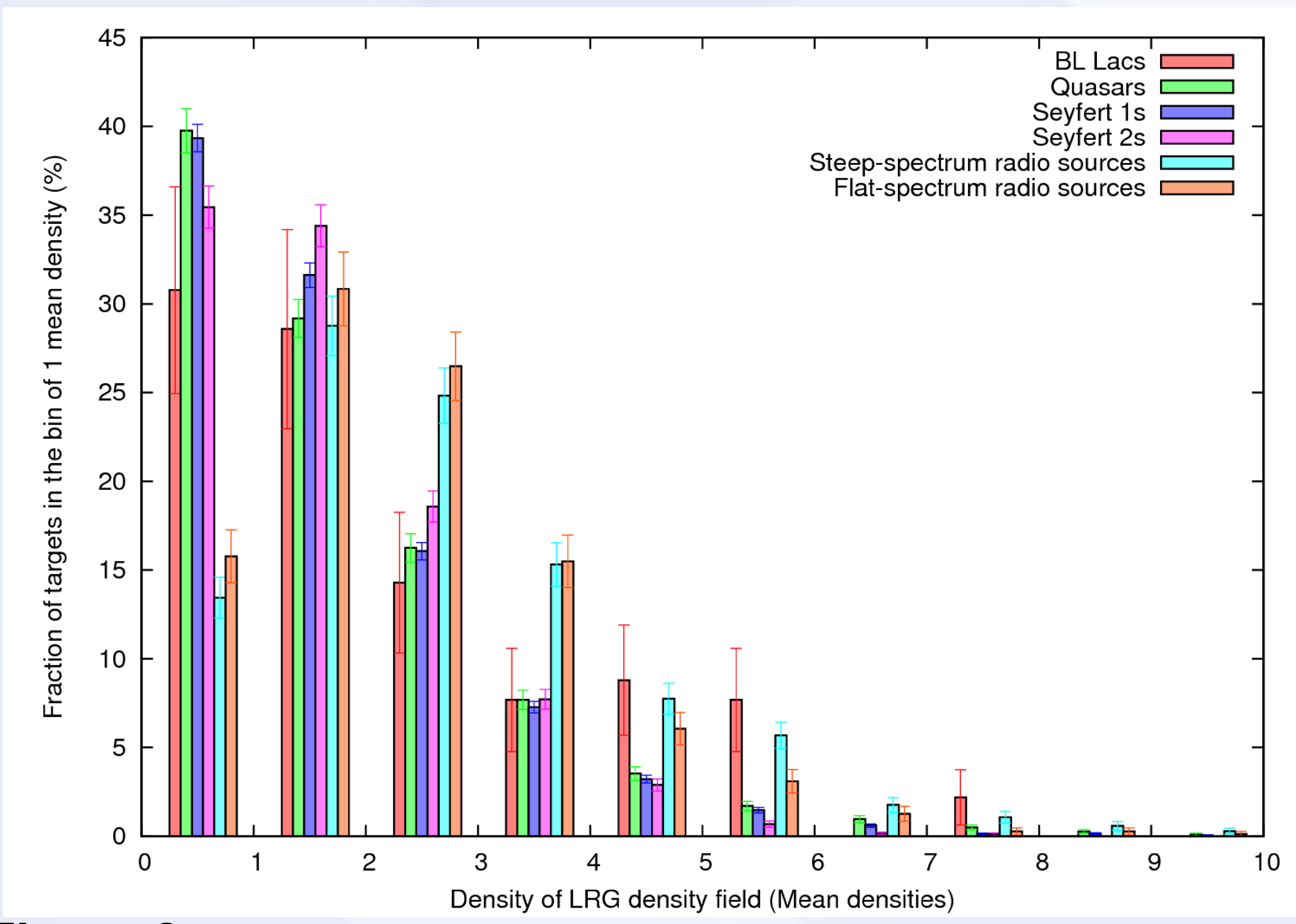

Figure 2
Distributions of AGN in different levels of environmental density. Each bar presents the percentage of objects in the bin of 1.0 times the mean density of the whole density field. The error bars show Poissonian errors.