AGN and Galaxy Clustering at z = 0.3 ~ 3.0 measured by using the Japanese Virtual Observatory (JVO)

Y. Shirasaki, M. Tanaka, M. Ohishi, Y. Mizumoto, T. Takata (NAOJ)、N. Yasuda (University of Tokyo, ICRR)

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jvo 検索

http://jvo.nao.ac.jp/portal

0. Abstract

Japanese Virtual Observatory (JVO) is an integrated database system developed by Astronomy Data Center of NAOJ. From the JVO, one can retrieve reduced archive data collected by the Subaru telescope, and also can access to any Virtual Observatories of the world. This poster describes an early science result of the JVO; study of the clustering of galaxies around an AGN. Using the data obtained through the JVO, we measured cross correlation between AGN and galaxy based on 1809 AGN samples. We found that the high redshift AGNs reside in an environment of higher galaxy density than AGNs in the local universe.

1. Introduction

According to the hierarchical galaxy formation model, it is assumed that a large galaxy has been formed through the collisions and mergers of smaller galaxies. During the galaxy evolution, a massive BH is formed at the center of the galaxy, and accretion of matters into the BH radiates large amount of energy, which is observed as an AGN. It is, therefore, expected that the AGN is located at higher density region where probability of the galaxy collision is high.

Based on large surveys such as SDSS and 2dF, the clustering property of AGN and galaxy has been measured up to z~0.6. To extend this measurement to higher redshifts, we need to carry out deep optical observations or medium deep infrared observations.

Using data archive of Subaru Suprime-Cam, it is possible to measure the environment of AGN at intermediate redshifts (z=1~2), which is difficult to be carried out with a smaller telescope. At this redshift range, the formation rate of AGN reaches a maximum and the super massive black holes were produced mostly at this epoch. Thus it is expected that the AGNs are found in the environment of high galaxy density, if they were produced mostly by galaxy mergers.

The study of the AGN environment may reveal a fundamental clue to the mechanism of AGN evolution and also for the evolution of large scale structure of the universe.

2. Dataset

We used the following dataset:

- 12th AGN Catalog by Veron-Cetty et al (AGN samples)
- SDSS DR-5 QSO Catalog (AGN samples)
- Subaru Suprime-Cam image archive (galaxy samples)
- UKIDSS DR2 (galaxy samples)

We searched the Suprime-Cam images and UKIDSS IR data around the AGNs listed in the AGN catalogs.

We analyzed 1809 AGN samples for redshift from 0.3 to 3.0.

The celestial distribution of the AGNs are shown in Figure 1, and the distribution of redshift and brightness of the AGNs are shown in Figure 2.

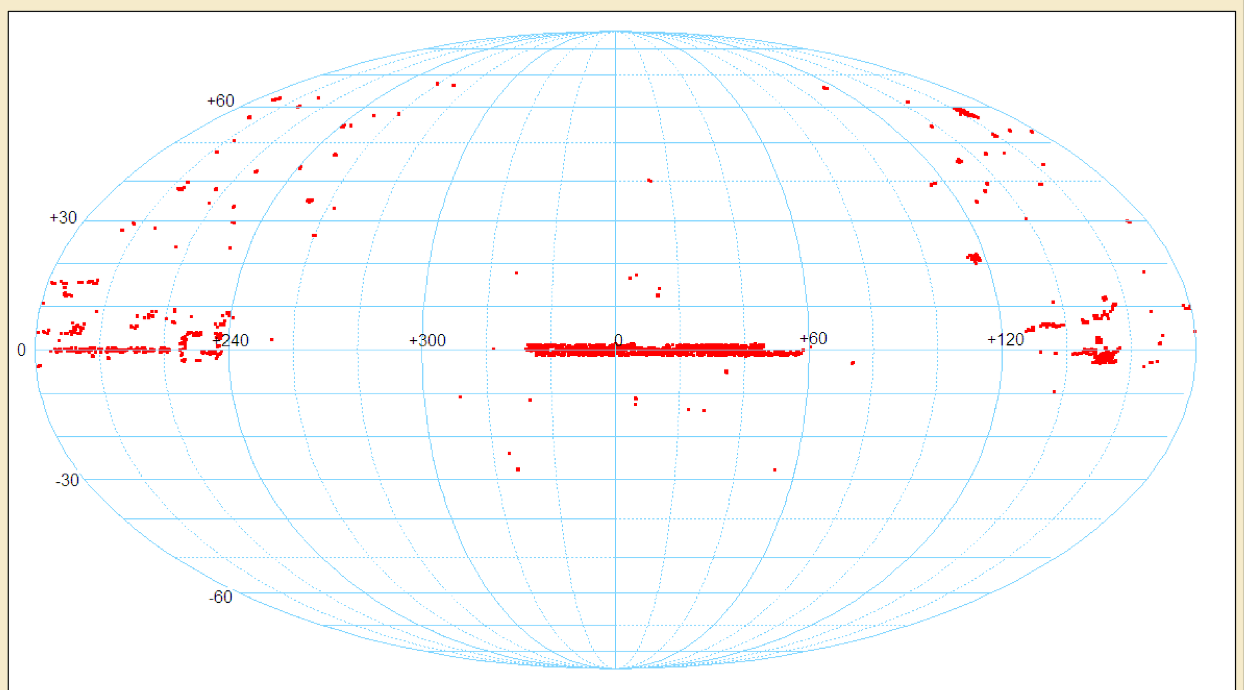

Figure 1 : The celestial distribution of the 1809 AGNs analyzed in this work. (equatorial coordinate)

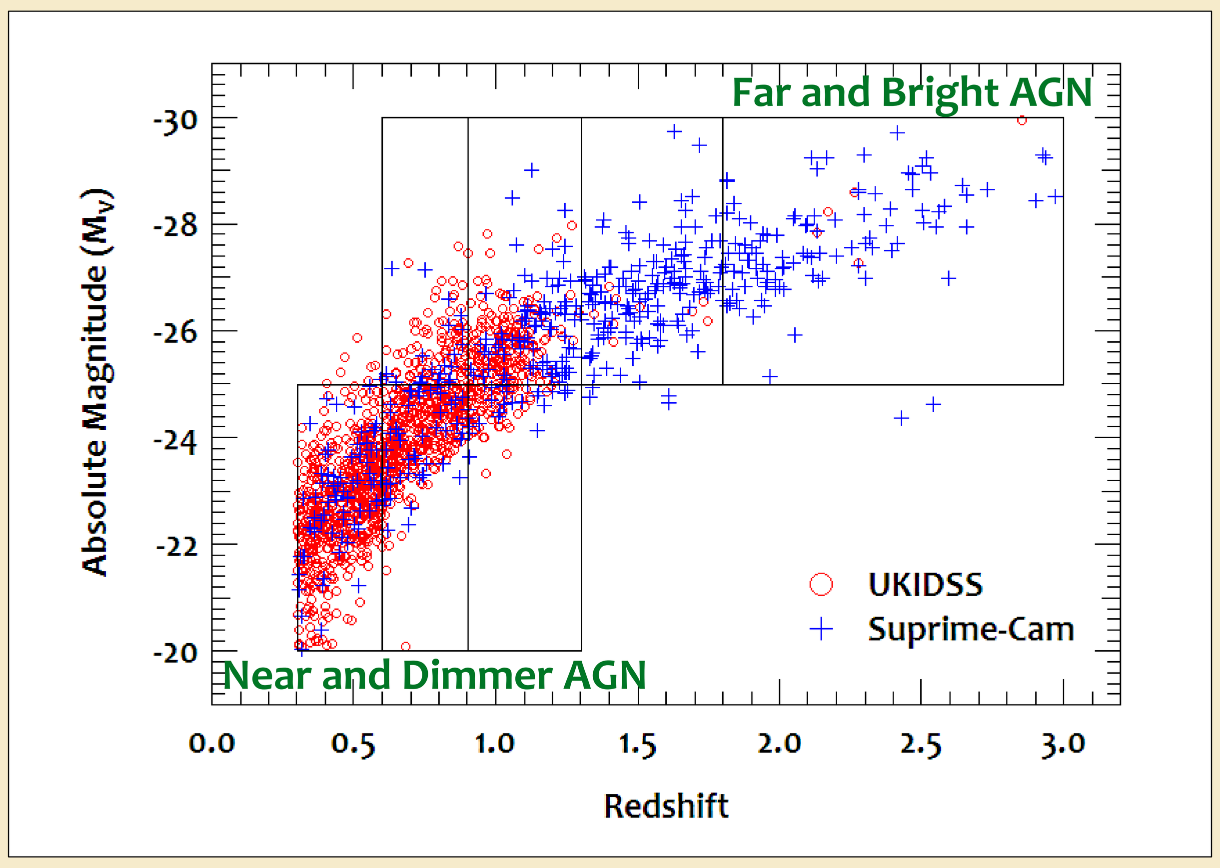

Figure 2 : K-corrected V band absolute magnitude vs redshift of the AGNs used in this work.

3. Analysis method

Studies of cross-correlation analysis usually use a method which compares the number count at each separation distance for an observed sample with that for a random catalog.

In this work, data of each AGN field are highly inhomogeneous, and it is difficult to create a random catalog to be compared with the observation. Thus we adopted the following method to estimate the projected cross correlation function, $\omega(r_p)$.

The projected cross correlation function is calculated by integrating the cross correlation function ξ along the line of sight as shown in Eq (1), where $\rho(r)$ is the number density of galaxies at a distance r from an AGN and n_{bg} is the surface density of background galaxies.

$$\omega(r_p) = \int_{-\infty}^{\infty} \xi(r_p, \pi) d\pi = \frac{1}{\rho_0} \int_{-\infty}^{\infty} [\rho(r) - \rho_0] d\pi = \frac{n(r_p) - n_{bg}}{\rho_0}, \quad (1)$$

We derived a surface density $n(r_p)$ as a function of projected distance from an AGN, and calculated the average for each redshift and brightness group. We also estimated the average number density ρ_0 of detectable galaxies at the AGN redshift from the luminosity function of galaxies. Then average of $\omega(r_p)$ is expressed as:

$$\omega(r_p) = \frac{\langle n(r_p) \rangle - \langle n_{bg} \rangle}{\langle \rho_0 \rangle}, \quad (2)$$

Assuming the power law model for the cross correlation function, we fit the model function to the observed surface density with two free parameters, correlation length and the average of the surface density of background galaxy $\langle n_{bg} \rangle$.

4. Result

- The projected cross correlation functions and correlation lengths were measured for seven redshift and brightness groups (Table 1 and Figure 3).
- σ_8 , which is a root mean square of the correlation function in the sphere with a comoving radius of $8h^{-1}$ Mpc, are compared in Figure 4.
- σ_8 increases with the redshift and it shows no significant dependence on the brightness of the AGN.
- It should be noted that the type of galaxies analyzed for each redshift group is not completely identical. The samples of the higher redshift groups are expected to be biased to the blue star-forming galaxies as they are observed at UV spectrum range in the rest frame.
- The distribution of galaxies around bright high-z AGNs (z4-B) is almost flat at < 2 Mpc, which indicates that the AGNs are not necessarily located at the center of galaxy distribution.

Group	z	$\langle z \rangle$*	M_V† mag	n_{AGN}‡	r_0§ h^{-1}Mpc	$\langle n_{bg} \rangle$‖ Mpc^{-2}	$\langle \rho_0 \rangle$# $10^{-3}Mpc^{-3}$
z1-D	0.3–0.6	0.46	−25.0–−20.0	651	$4.7^{+1.3}_{-0.7}$	22.1 ± 0.07	$4.3^{+0.7}_{-1.1}$
z2-D	0.6–0.9	0.73	−25.0–−20.0	420	$5.8^{+1.9}_{-1.1}$	10.1 ± 0.05	$1.9^{+0.4}_{-0.6}$
z3-D	0.9–1.3	1.01	−25.0–−20.0	100	$7.6^{+3.2}_{-1.9}$	11.2 ± 0.07	$1.6^{+0.4}_{-0.5}$
z2-B	0.6–0.9	0.79	−30.0–−25.0	113	$6.3^{+2.4}_{-1.5}$	13.9 ± 0.10	$2.3^{+0.4}_{-0.6}$
z3-B	0.9–1.3	1.06	−30.0–−25.0	274	$5.1^{+2.7}_{-1.5}$	11.1 ± 0.04	$1.4^{+0.4}_{-0.5}$
z4-B	1.3–1.8	1.54	−30.0–−25.0	142	$11.1^{+6.1}_{-2.7}$	19.4 ± 0.07	$1.3^{+0.4}_{-0.6}$
z5-B	1.8–3.0	2.07	−30.0–−25.0	109	< 13.1	14.4 ± 0.07	$0.49^{+0.19}_{-0.24}$
z1-D (IR)	0.3–0.6	0.46	−25.0–−20.0	584	$6.8^{+1.9}_{-1.0}$	7.73 ± 0.05	$2.2^{+0.4}_{-0.6}$
z1-D (OPT)	0.3–0.6	0.46	−25.0–−20.0	67	$3.0^{+1.5}_{-1.1}$	147.0 ± 0.67	$22.3^{+2.8}_{-4.6}$
z2-D (IR)	0.6–0.9	0.73	−25.0–−20.0	374	$7.4^{+4.7}_{-2.1}$	3.50 ± 0.03	$0.56^{+0.22}_{-0.27}$
z2-D (OPT)	0.6–0.9	0.74	−25.0–−20.0	46	$5.0^{+1.6}_{-1.0}$	63.5 ± 0.34	$12.7^{+1.8}_{-2.9}$

* Average redshift.
† K-corrected absolute magnitude range.
‡ Number of AGNs.
§ Correlation length, the quoted errors contain systematic errors due to uncertainty of ρ_0 and one sigma statistical errors. The error does not include covariance of number densities at each distance bins.
‖ Projected galaxy number density for background.
Average galaxy number density at the AGN redshift.

Table 1 : Fitting parameters of projected cross correlation analysis.

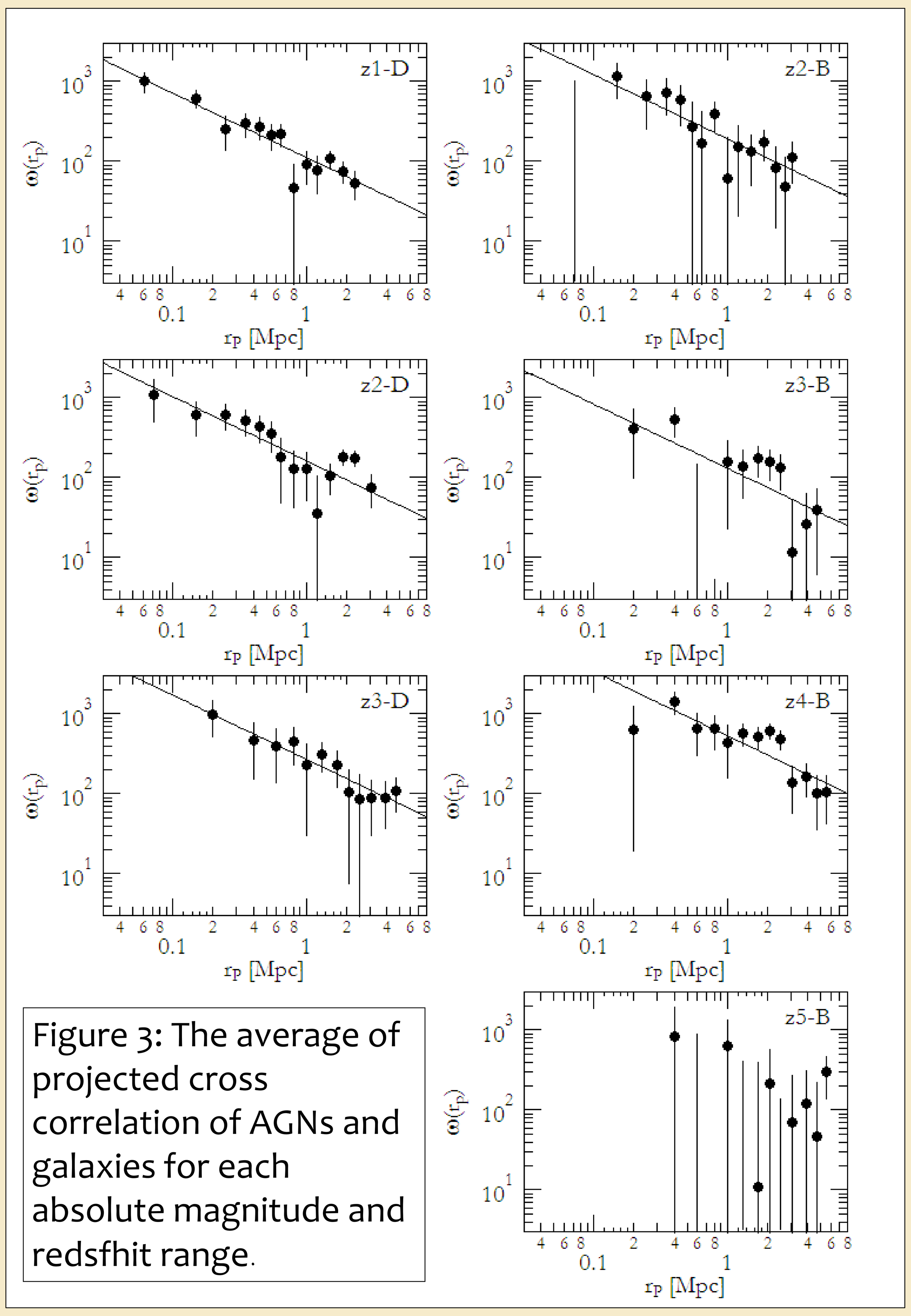

Figure 3: The average of projected cross correlation of AGNs and galaxies for each absolute magnitude and redsfhit range.

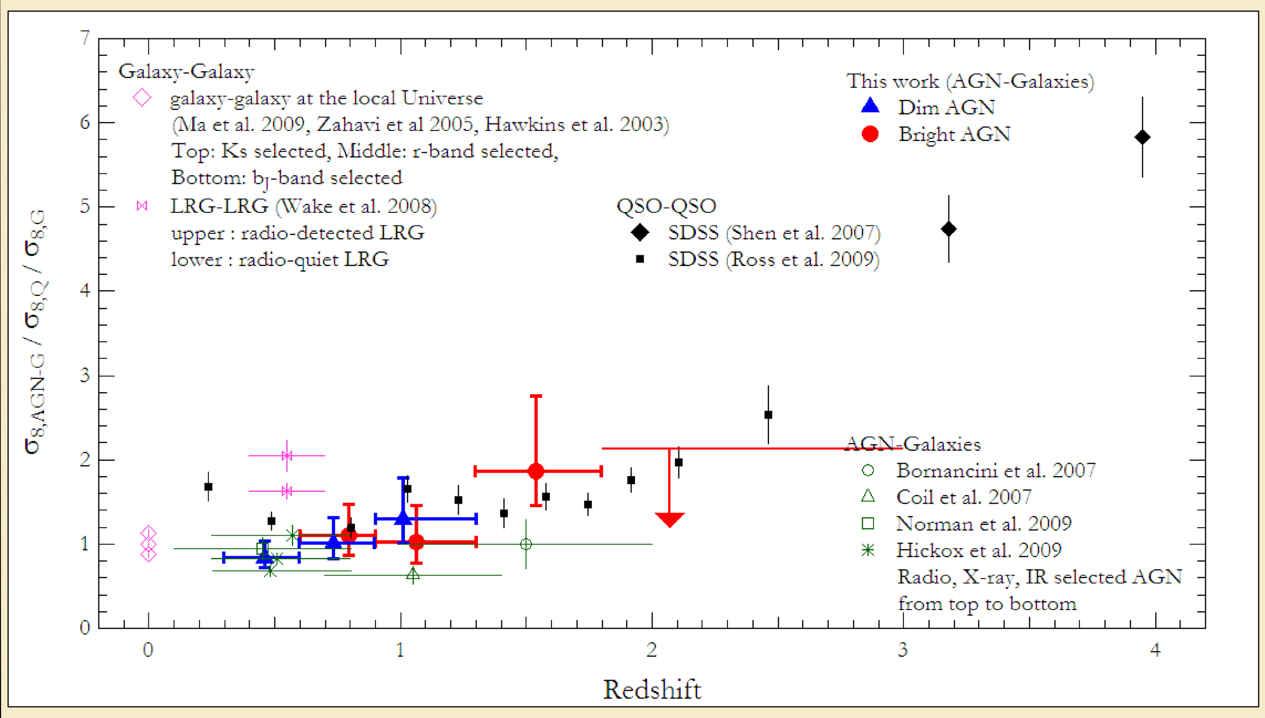

Figure 4 : The σ_8 of the galaxies around AGNs as a function of redshift.

5. Conclusions

- We developed a method to measure the cross correlation function of AGN and galaxy from imaging data only, which enabled to investigate the galaxy distribution around an AGN at a small scale with high statistic.
- We succeeded to measure the cross correlation at redshifts higher than 0.6 with better statistics than ever achieved by using deep imaging data of Subaru Suprime-Cam retrieved from the JVO.
- Our result shows that AGNs at higher redshift (z > 1.0) reside in a denser environment than lower redshift AGNs, which supports a galaxy merger scenario for evolution of a supermassive black hole.