AGN-Galaxy clustering and its dependence on the mass of the SMBH

This work is based on
Shirasaki et al. 2011, PASJ, 63S, 469
Komiya et al. 2013, ApJ, 775, 43
Shirasaki et al. 2014 (in preparation)

Yuji Shirasaki
National Astronomical Observatory of Japan

Introduction

- Ubiquity of SMBH.
- Co-evolution of galaxies and SMBHs.
- Effect of large scale environment on the evolution of galaxies.
- SMBH is a key element in the evolution of galaxies and large scale structure of universe.
- Two scenarios for the evolution of SMBH
  - secular evolution (bar instability ...)
  - merger (major, minor), interaction with nearby galaxy
- Environment of SMBH

Study on environment of AGN

- X-ray selected AGN : similar to red galaxies (Coil +09).
- Radio AGN strongly clustered, X-ray AGN clustered similarly with the typical galaxies, IR AGN weakly clustered (Hickox+09).
- Different selections don't significantly change the clustering for broad-line AGNs (Krumpe+12).

These classification is based on the temporal property; should be compared in integrated quantity : M_{BH}

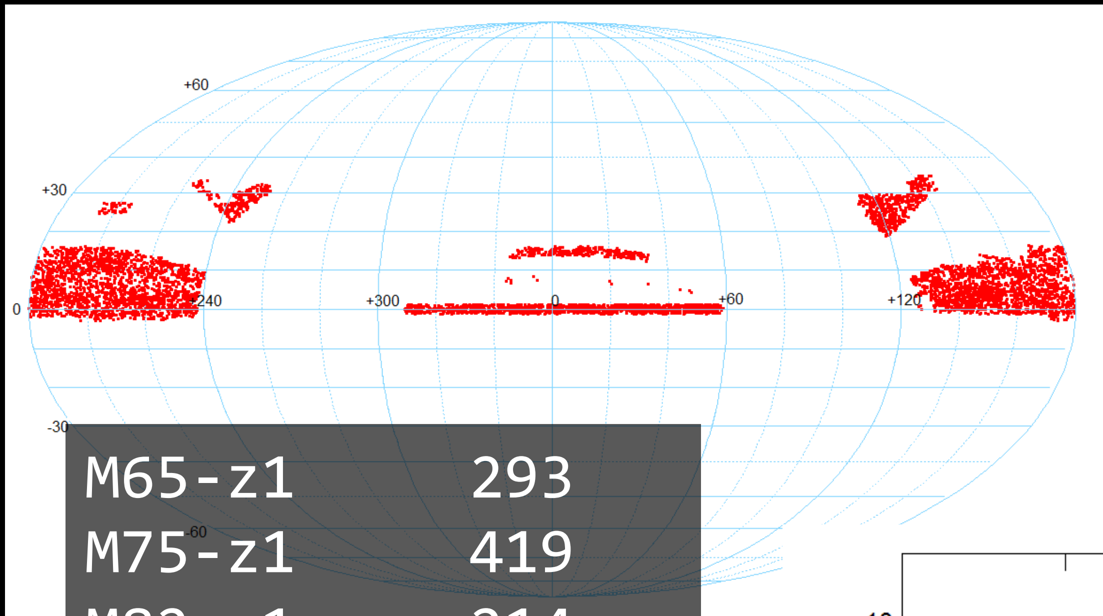
- The most massive (top 10%) QSOs are clustered stronger than those of lower mass QSOs at the ~2 sigma level (Shen+09).

Objectives of this work

- Measure the clustering strength as a function of BH mass in good precision to investigate a signature of mass accretion controlled by an external factor.
- Examine which type of galaxy (red or blue) are dominant at AGN environment to infer the evolutional stage of the system.
- Examine the luminosity function of galaxies around AGN to find a signature of merger at low luminosity.

AGN-Galaxy clustering using photometric galaxy catalog

Dataset



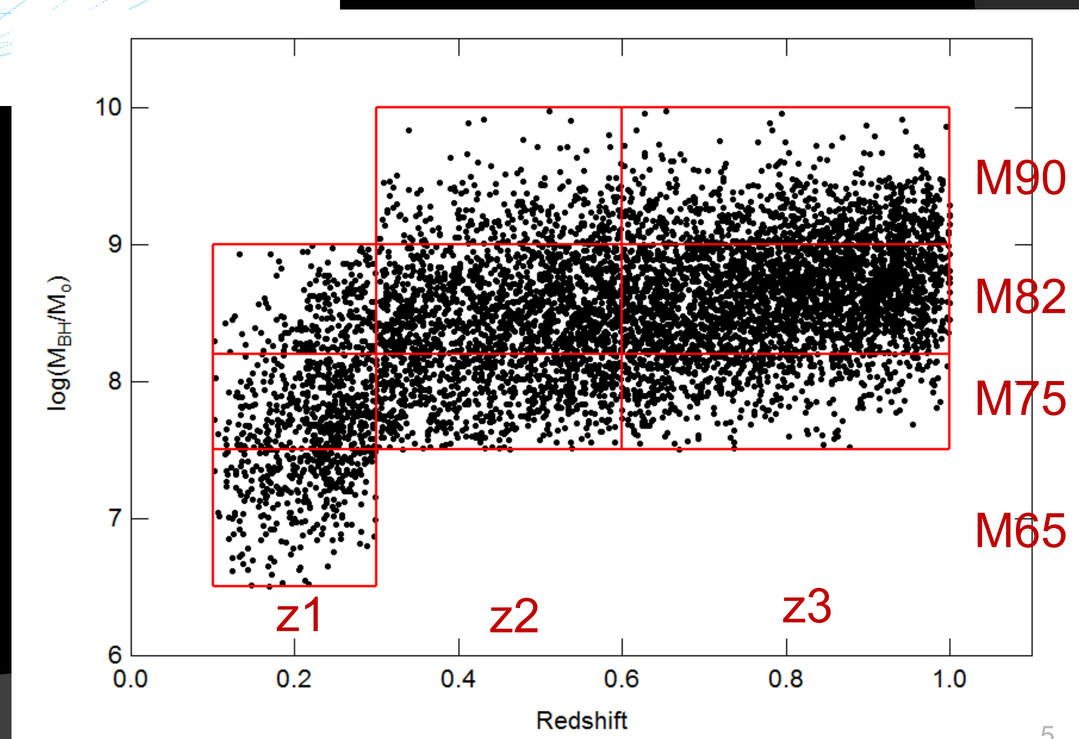
M65-z1	293
M75-z1	419
M82-z1	214
M75-z2	702
M82-z2	1184
M90-z2	253
M75-z3	507
M82-z3	2345
M90-z3	722
Total	6639

AGN catalog (M_{BH})

- Shen+11
- Green&Ho07

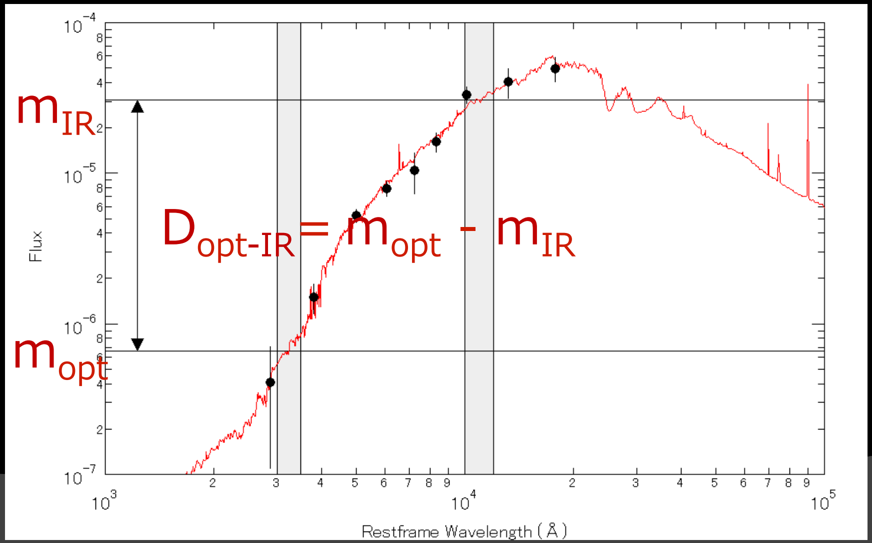
Galaxy catalog

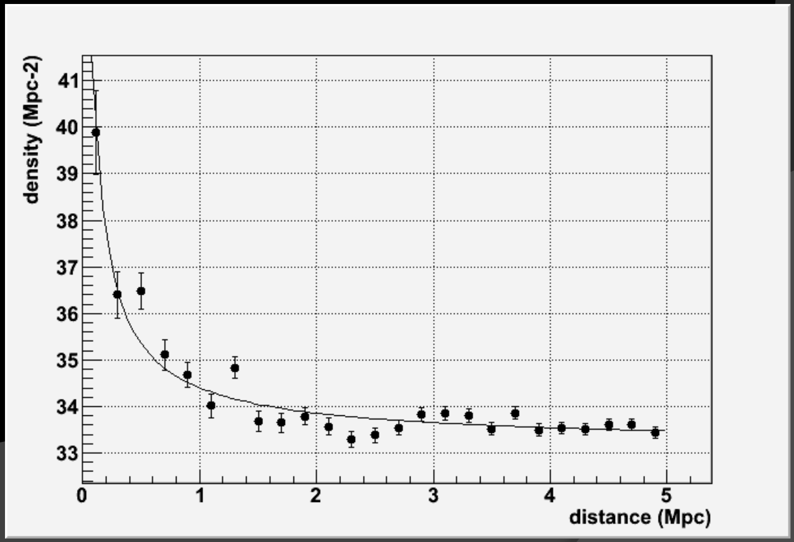
- SDSS DR8
- UKIDSS DR9



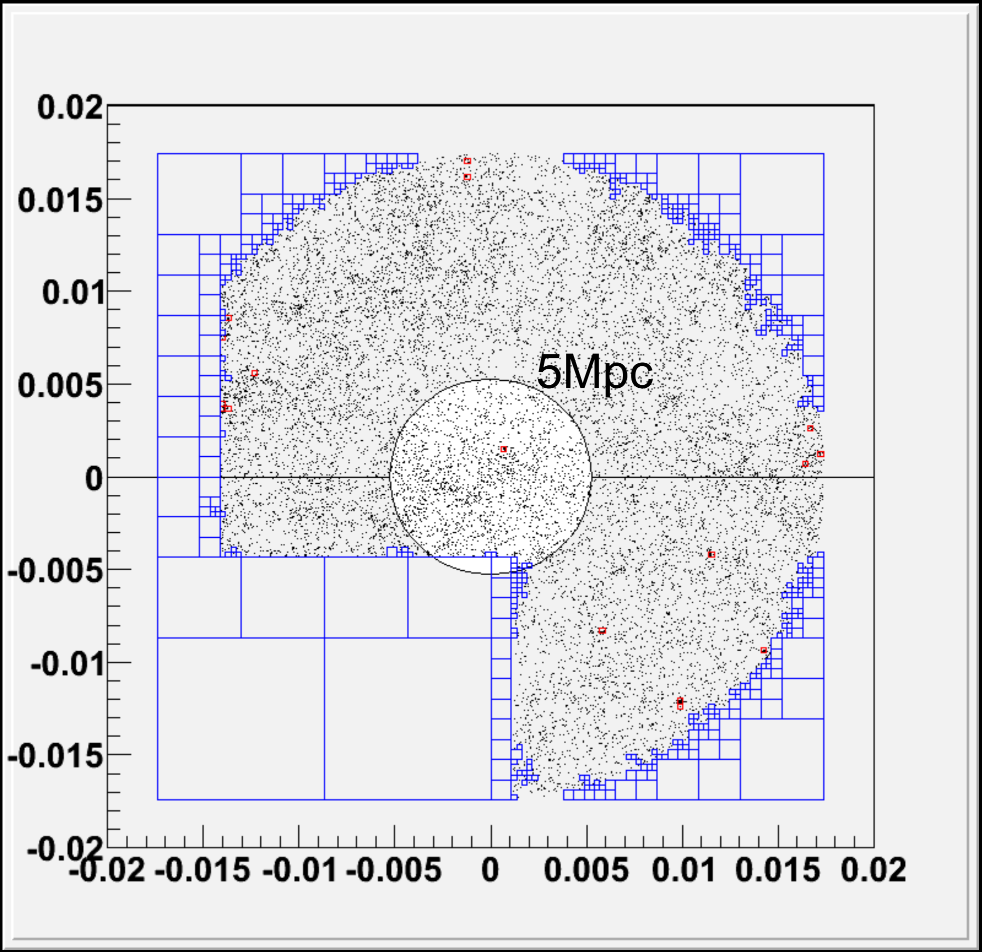
Analysis procedure

1. Retrieve data (position, magnitude) of galaxies around AGNs from SDSS and UKIDSS database .
2. Create a merged catalog for each AGN.
3. Perform SED fitting at redshift of AGN by EAZY software (Brammer+08).
4. Calculate $D_{opt\text{-}IR}$ parameter for separating blue/red galaxies.
5. Check the data coverage and uniformity of the AGN field.
6. Calculate number densities as a function of projected distance from AGN.
7. Stacking all the number density profiles and obtain its average for a group of AGN



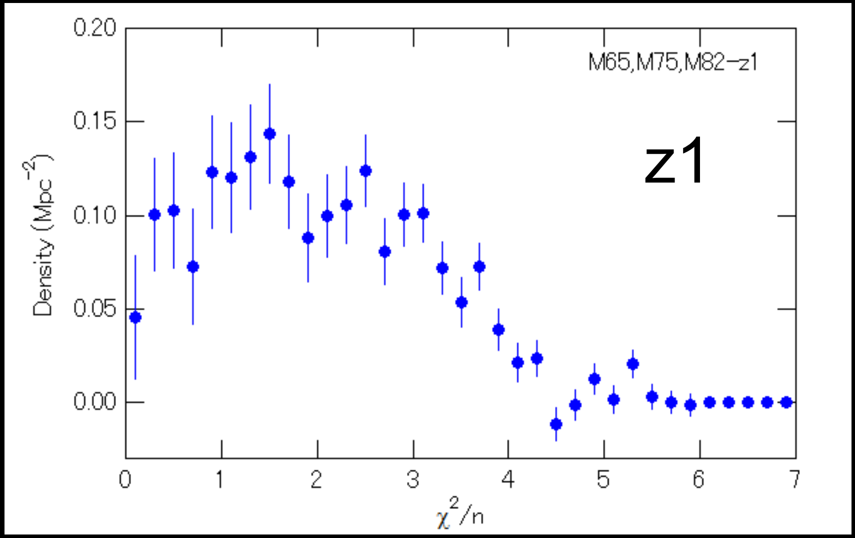


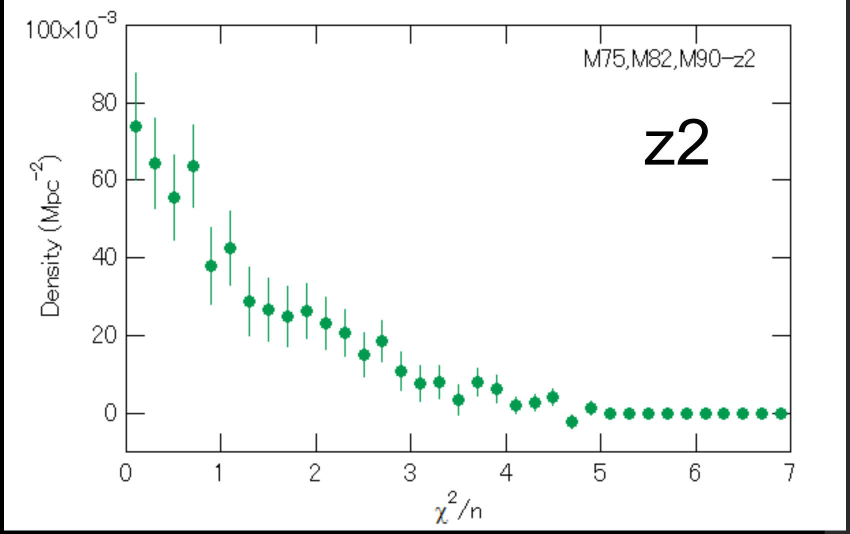
Field quality check

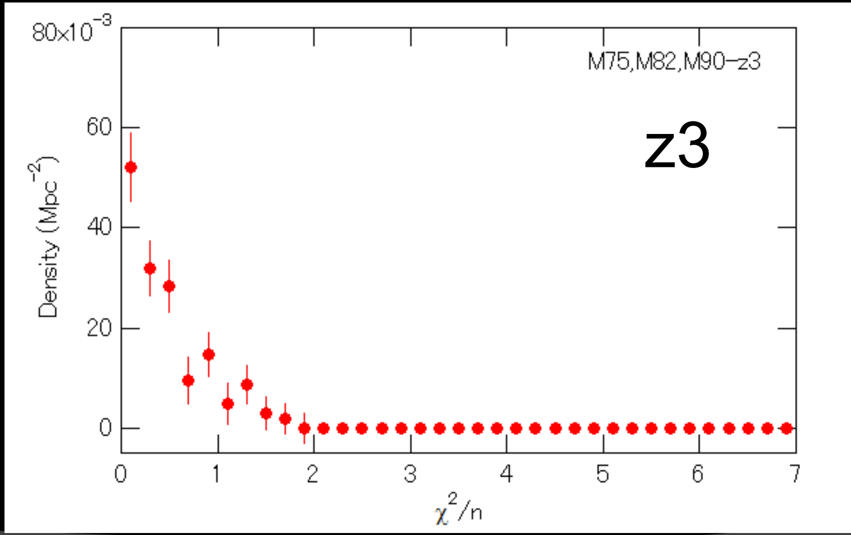


- Remove a sample that has a partial coverage (<80% coverage in any annulus of 0.2 Mpc width) at < 5 Mpc.
- Remove a sample that shows highly non-uniform number density profile. Consider it as an accidental alignment of nearby cluster (see Komiya+13).
- Mask the region where local density deviates by 7 sigma. It is a typically noise around a bright star.

χ^2 cut based on the SED fitting







	threshold	rejection
z = 0.1 ~ 0.3	6.0	3%
0.3 ~ 0.4	5.0	5%
0.4 ~ 0.6	4.0	9%
0.6 ~ 1.0	2.0	27%

Method for calculating r_0

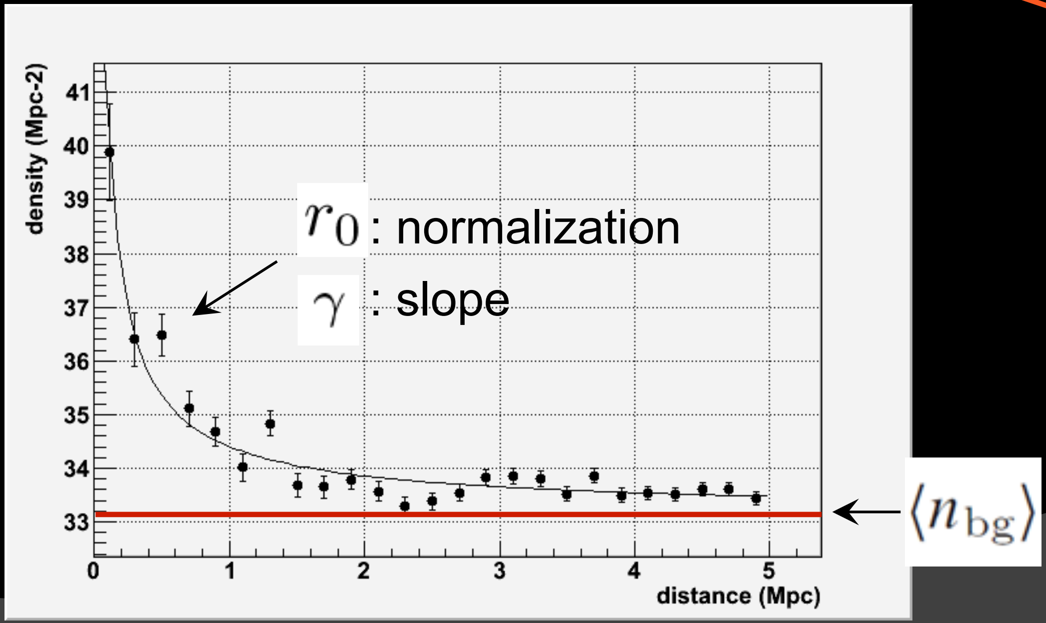
$$\rho(r) = \rho_0 \left\{ 1 + \left(\frac{r_0}{r} \right)^\gamma \right\}$$

γ = 1.8 (fixed)

$$\langle n(r_\mathrm{p}) \rangle = r_\mathrm{p} \left(\frac{r_0}{r_\mathrm{p}} \right)^\gamma \frac{\Gamma(1/2)\Gamma[(\gamma-1)/2]}{\Gamma(\gamma/2)} \langle \rho_0 \rangle + \langle n_\mathrm{bg} \rangle$$

free parameters

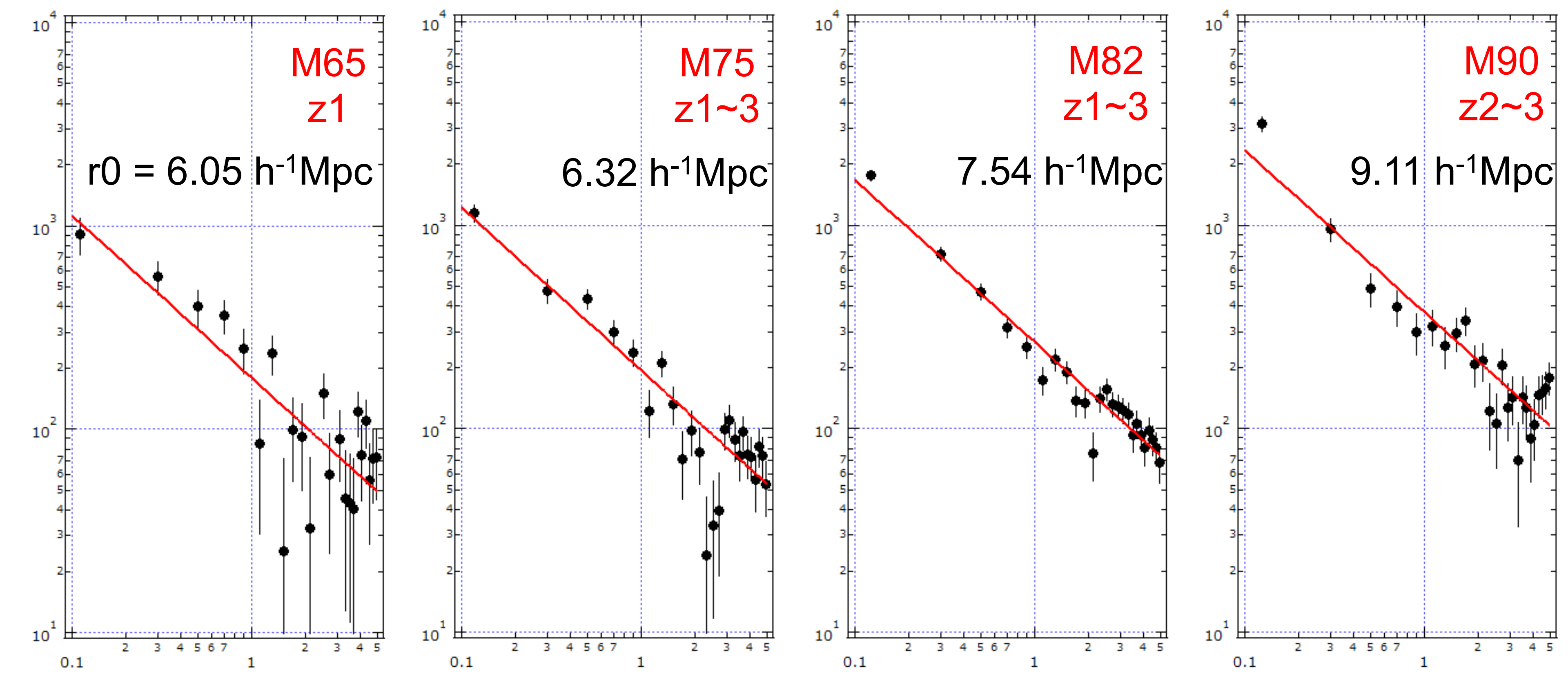
derived from luminosity function and detection efficiency function (see Komiya+13)



Projected cross correlation : $\omega(r_p)$

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

$\omega(r_p)$ [Mpc]

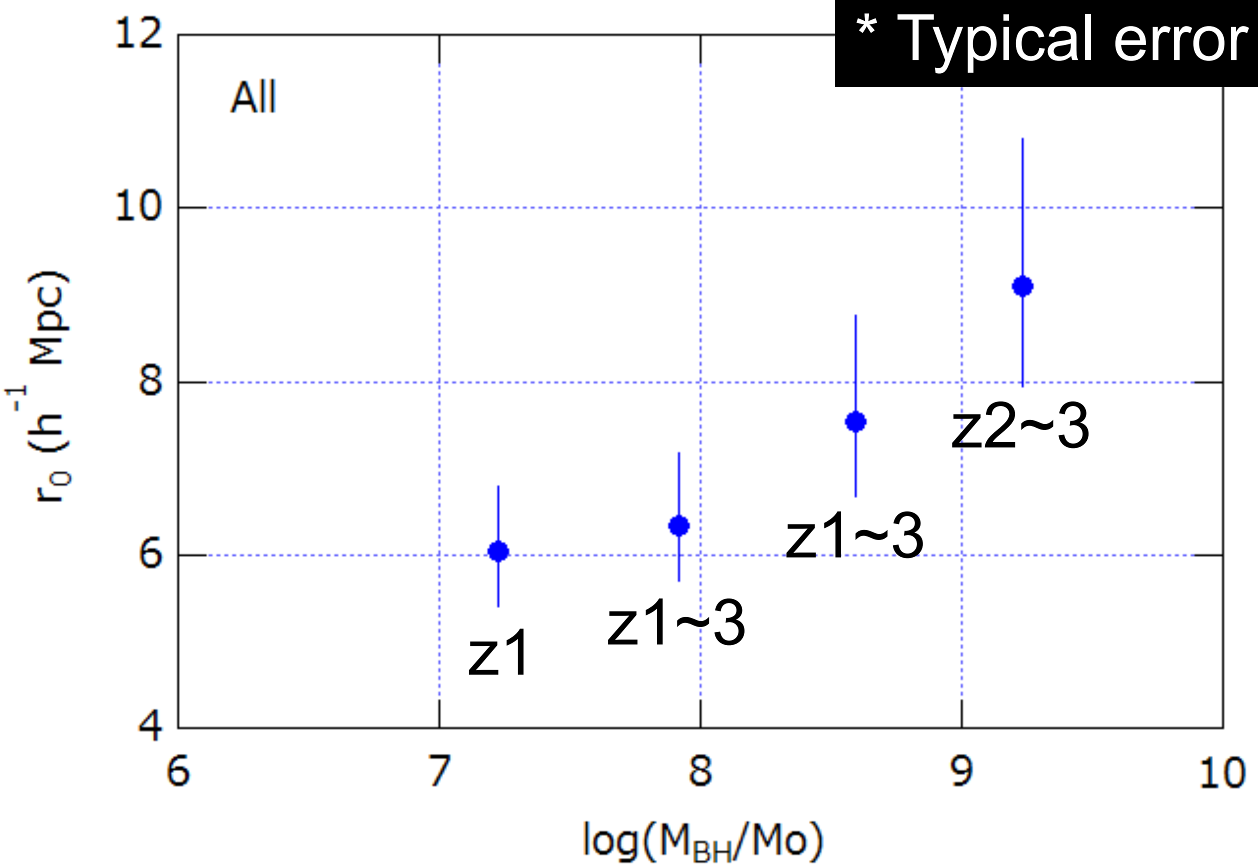


Projected distance from AGN [Mpc]

M_{BH} dependence of r_0

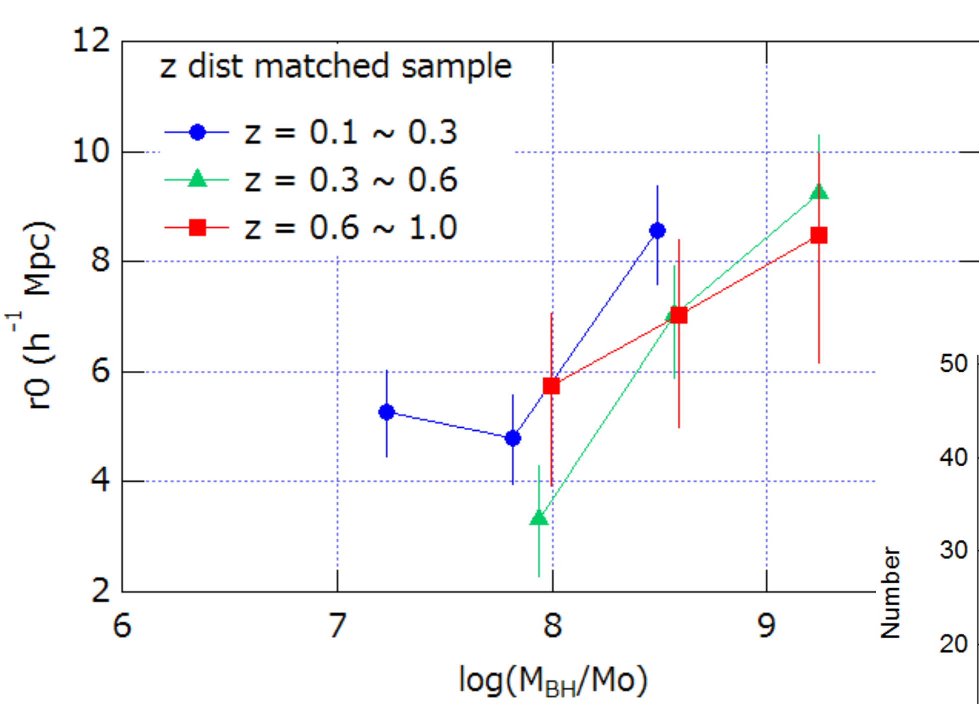
* The error bars include 1 σ statistical error and systematic error due to the uncertainty of ρ_0

* Typical error of M_{BH} is 0.3 dex.



M_{BH} dependence of r_0 for each z range

* To reduce the redshift dependence, z-matched samples are constructed so that each point of the same redshift rage has the same redshift distribution.

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number of sample
---------------------
M65,75,82-z1   172
M75,82,90-z2   253
M75,82,90-z3   441
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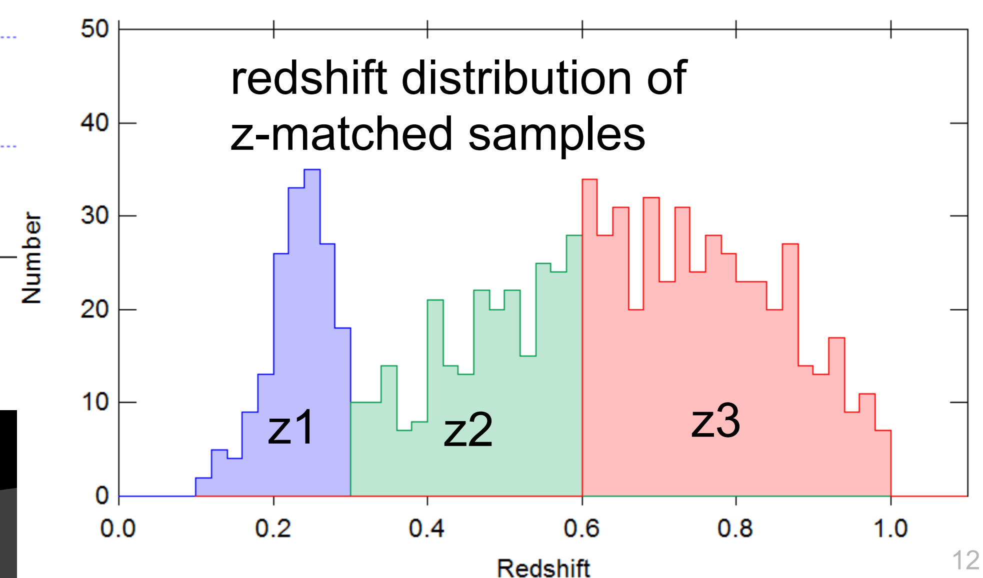
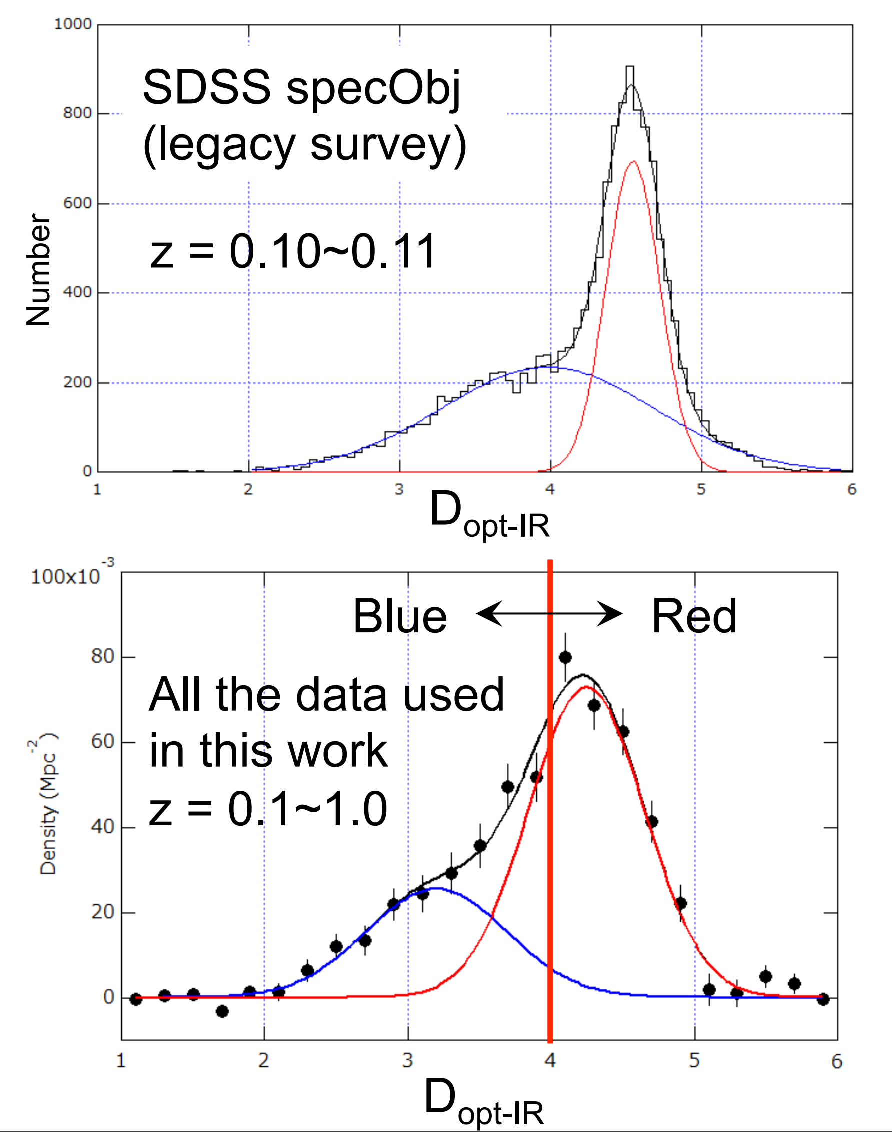


Blue/Red galaxy fraction



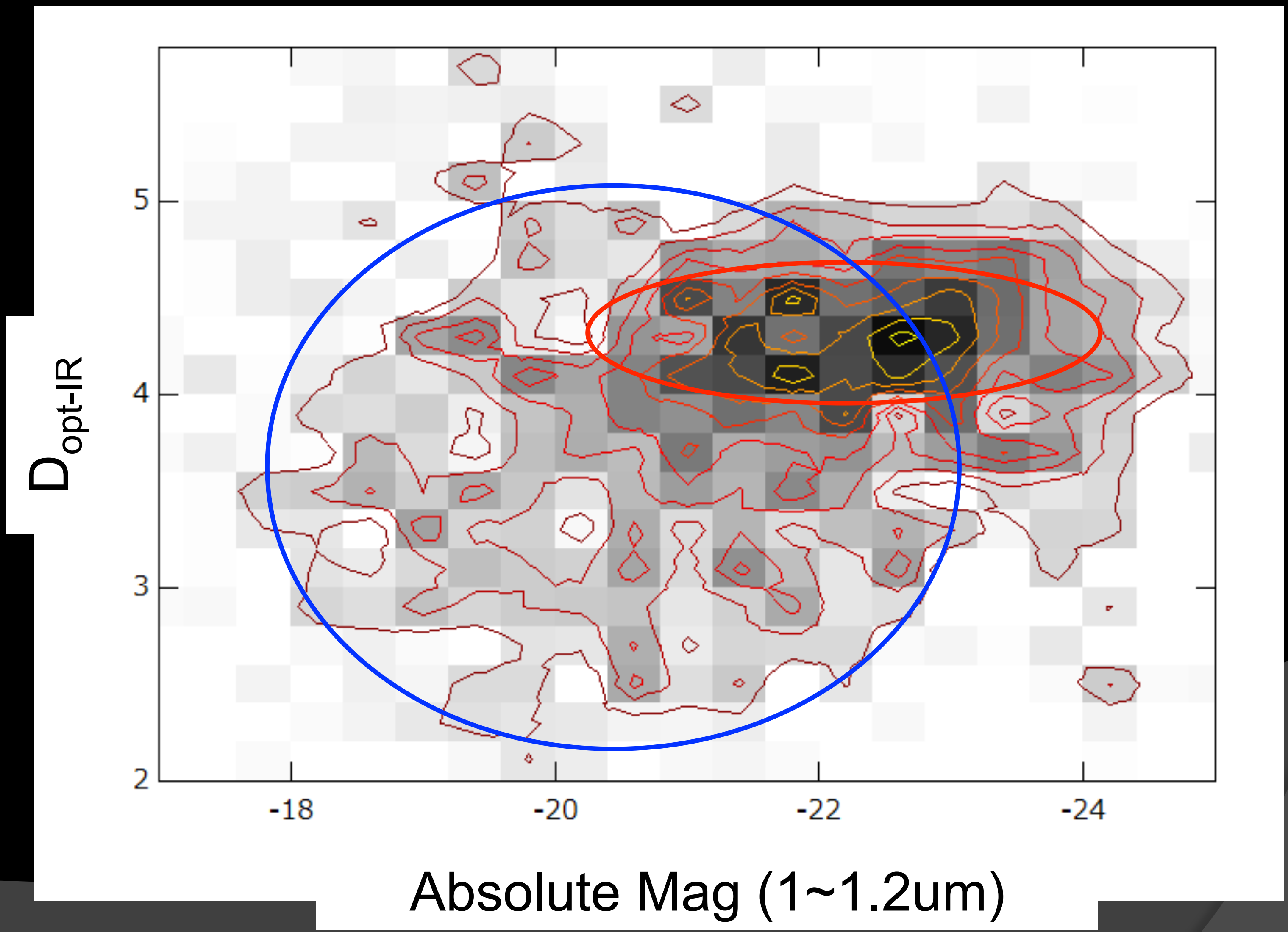
- What type of galaxy contributes to the increase of clustering at high M_{BH}.
- It is well known that galaxies shows a bimodality in the color-magnitude plane : red sequence and blue cloud.
- D-distribution of galaxies associated with AGNs can be obtained by $n_{in}(D) – n_{out}(D)$.

in: r = 0 ~ 1 Mpc

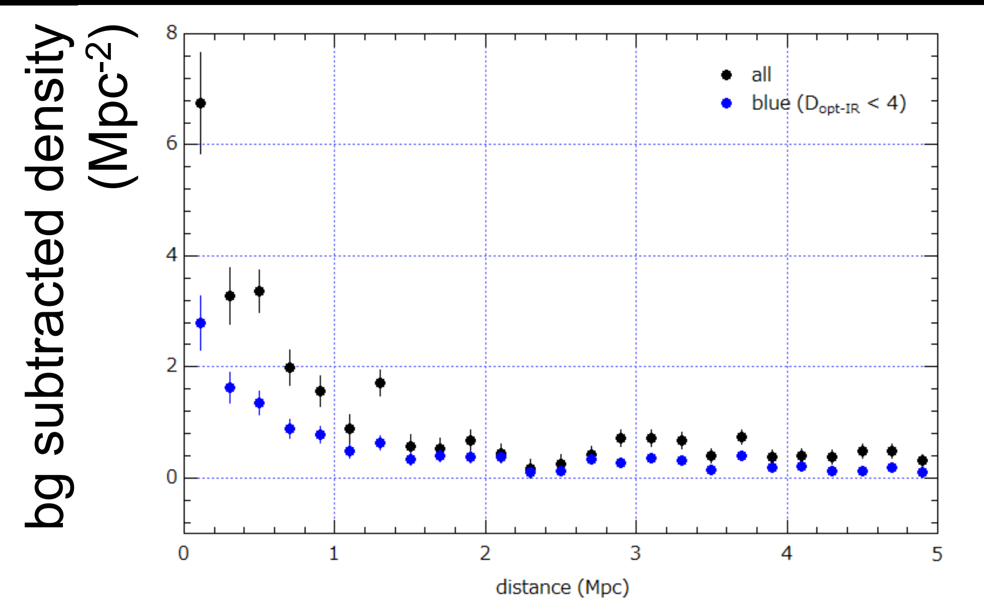
Out : r = 3 ~ 5 Mpc

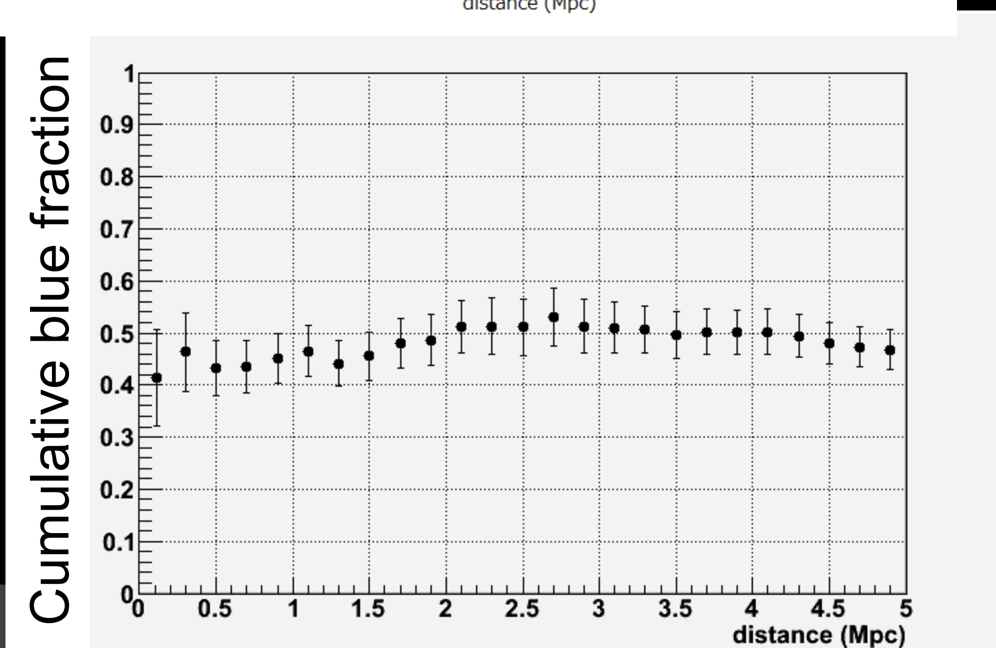
Color-Luminosity diagram

From all the data used in this work



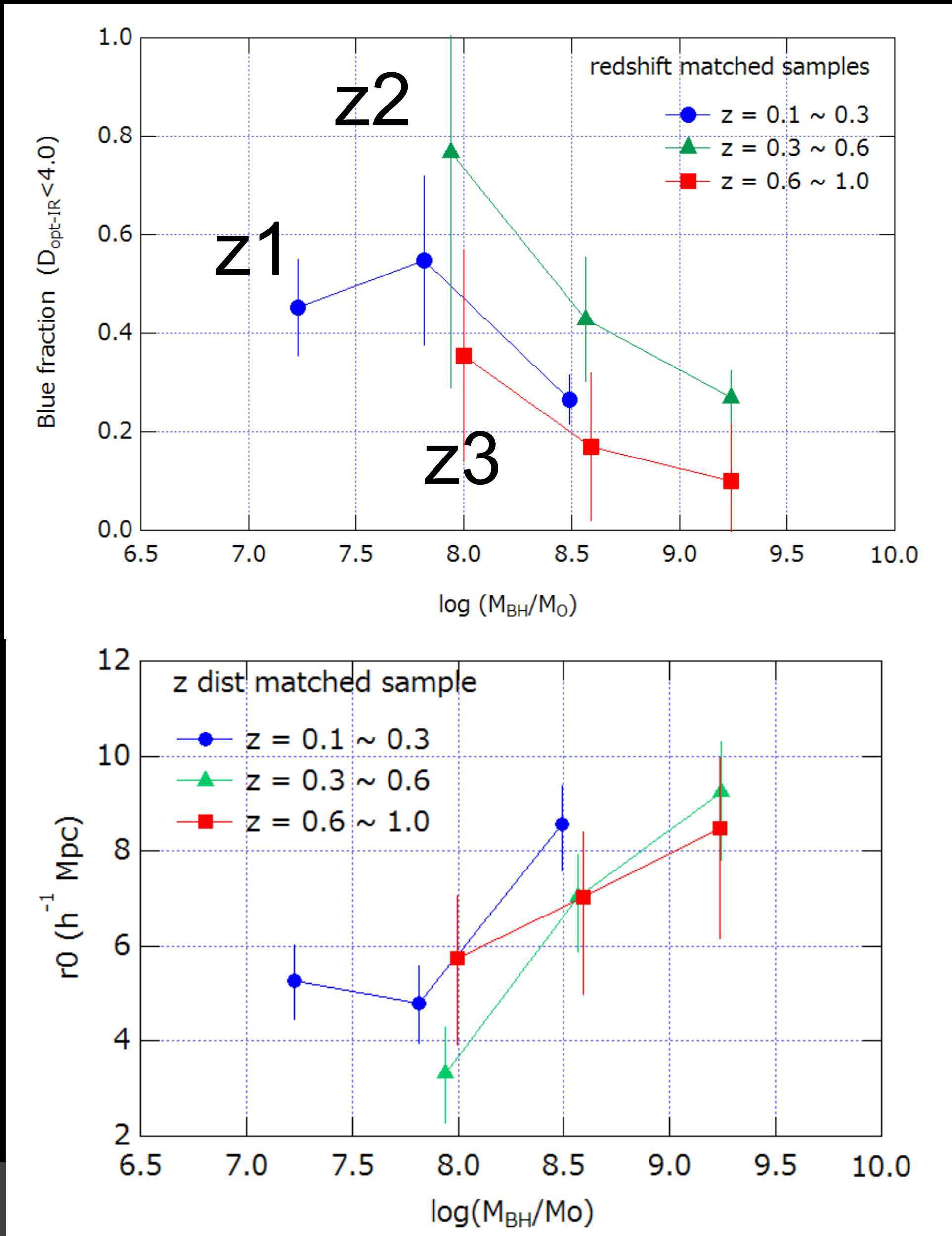
Blue fraction : method





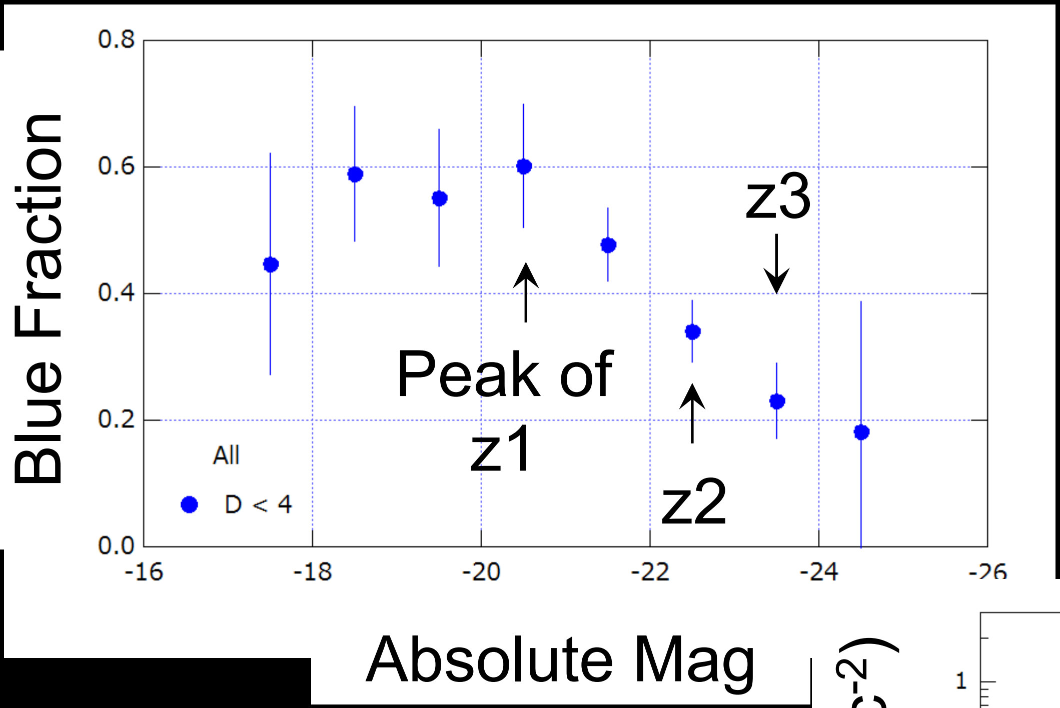
1. Derive radial profiles of number density for all and blue ($D_{opt\text{-}IR}$ < 4) galaxy samples.
2. Fit to the model function to obtain background surface density (bg)
3. Calculate cumulative fraction of blue galaxies by integrating the number ratio of blue to all.

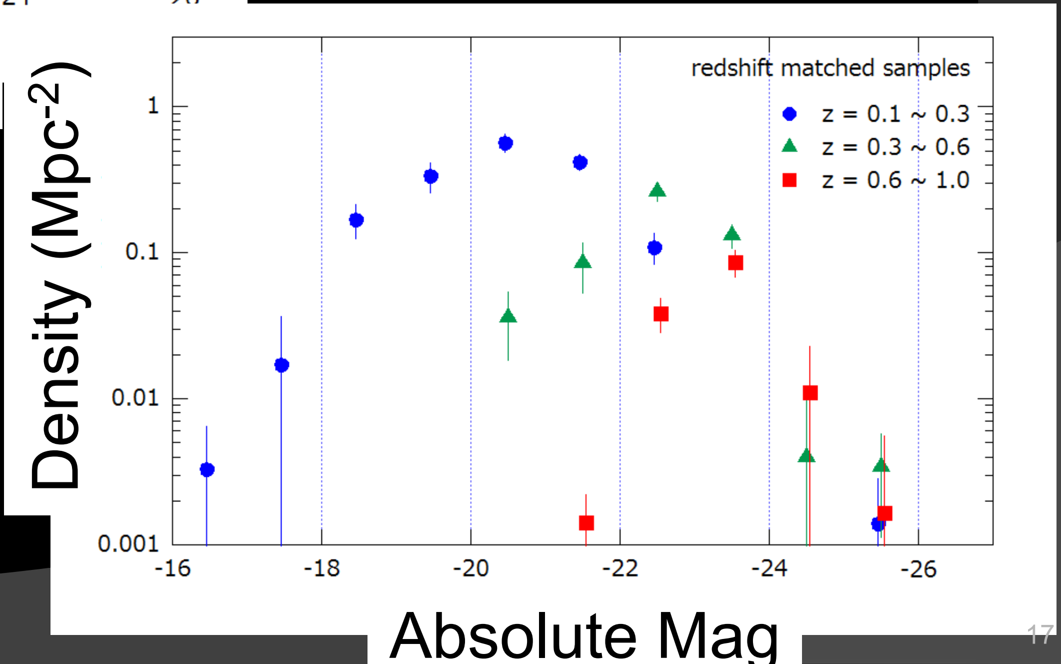
Blue fraction : result



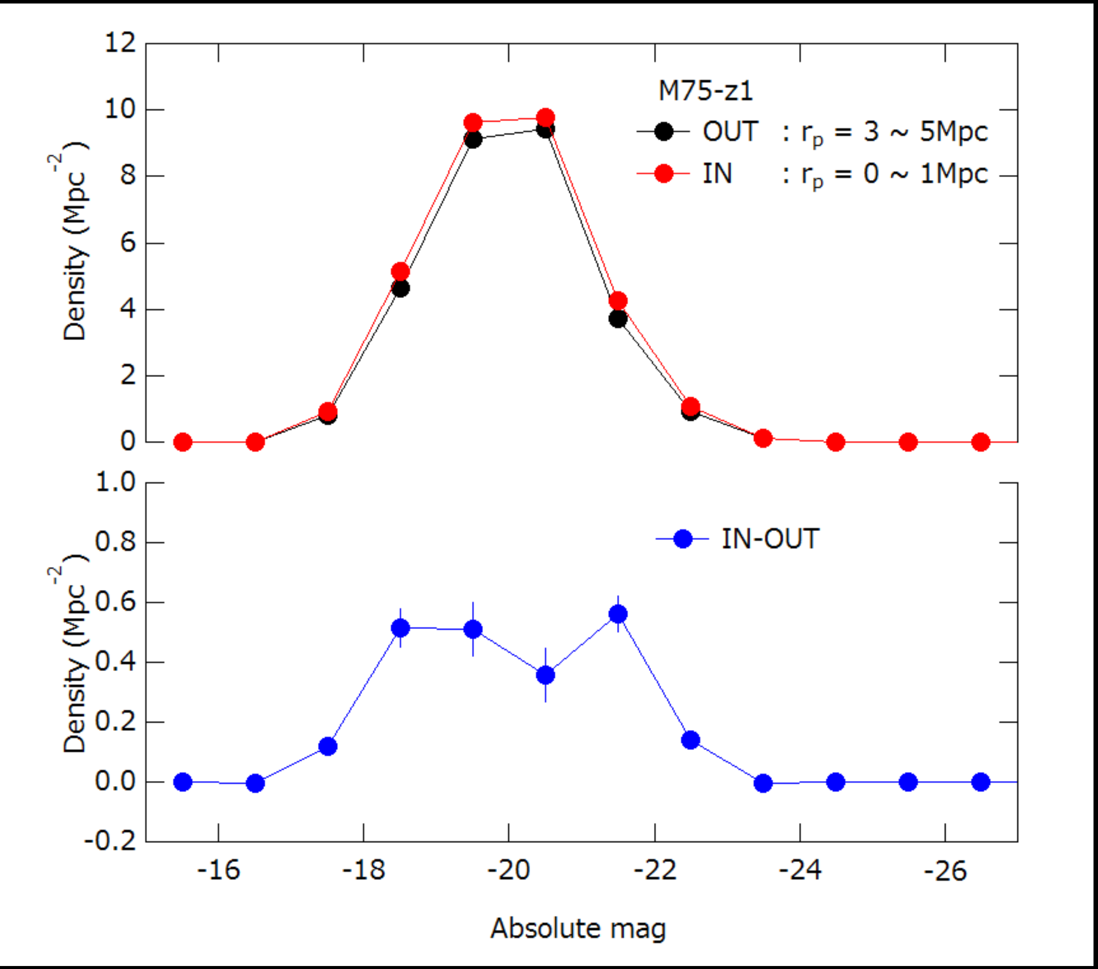
- Blue fraction at < 1Mpc are plotted as a function of M_{BH}.
- Samples matched in redshift are used for each redshift range.
- Fraction of blue galaxies decreases as M_{BH} increases, and well correlate with r_0.
- As blue galaxies are typically dimmer than the red galaxies, a large fraction of blue galaxies are below the detection limit at redshit > 0.6 (z3).

Blue fraction vs Absolute mag



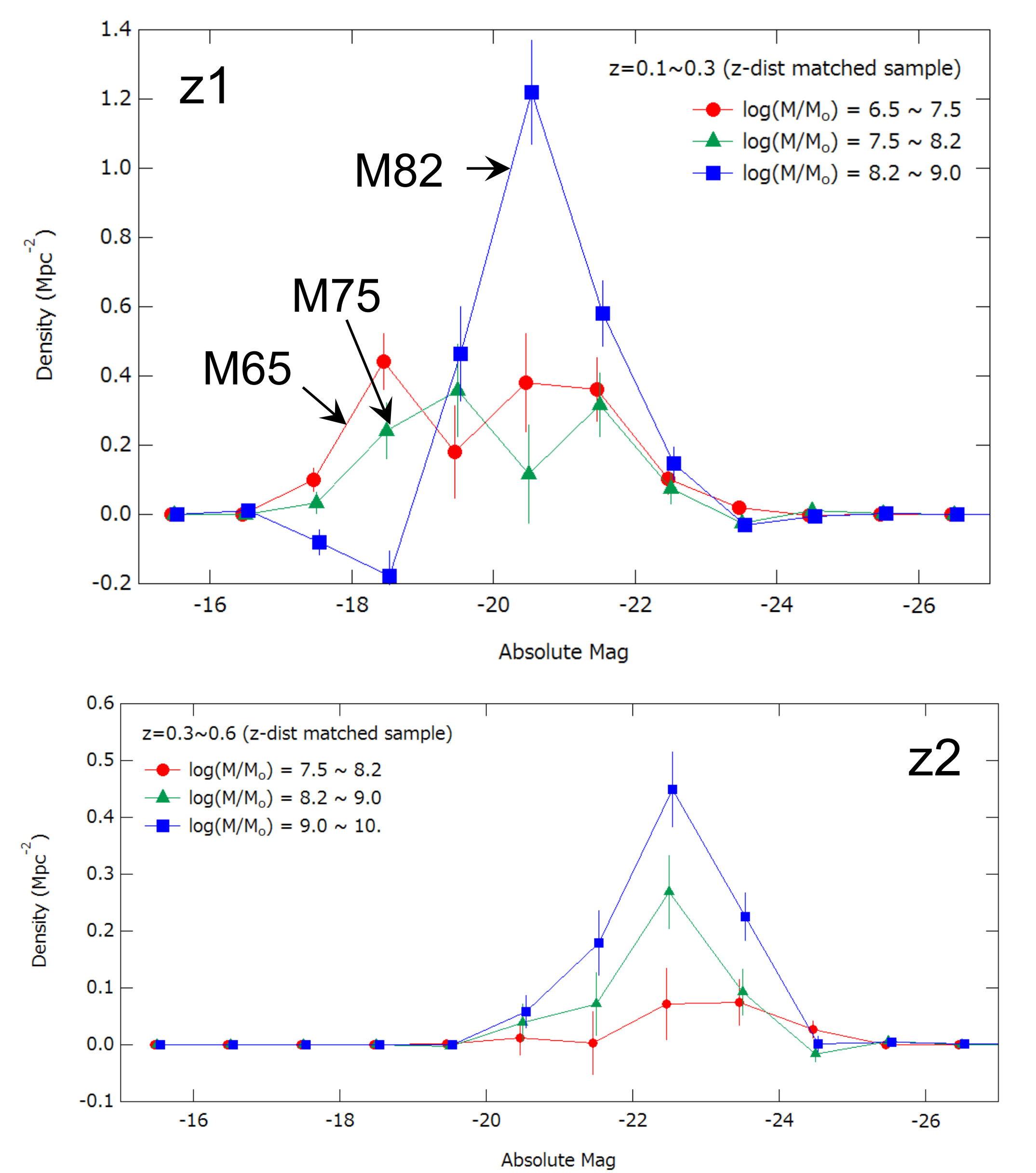


Luminosity function : method



- Mergers distorts the luminosity function
- less luminous galaxies are swallowed into luminous galaxies and increase the brightness.
- LF is depleted at dimmer side and enhanced at brighter side by mergers
- (uncorrected) LF can be obtained by $n_{in}(M) - n_{out}(M)$.

Luminosity function : result



Redshift matched samples

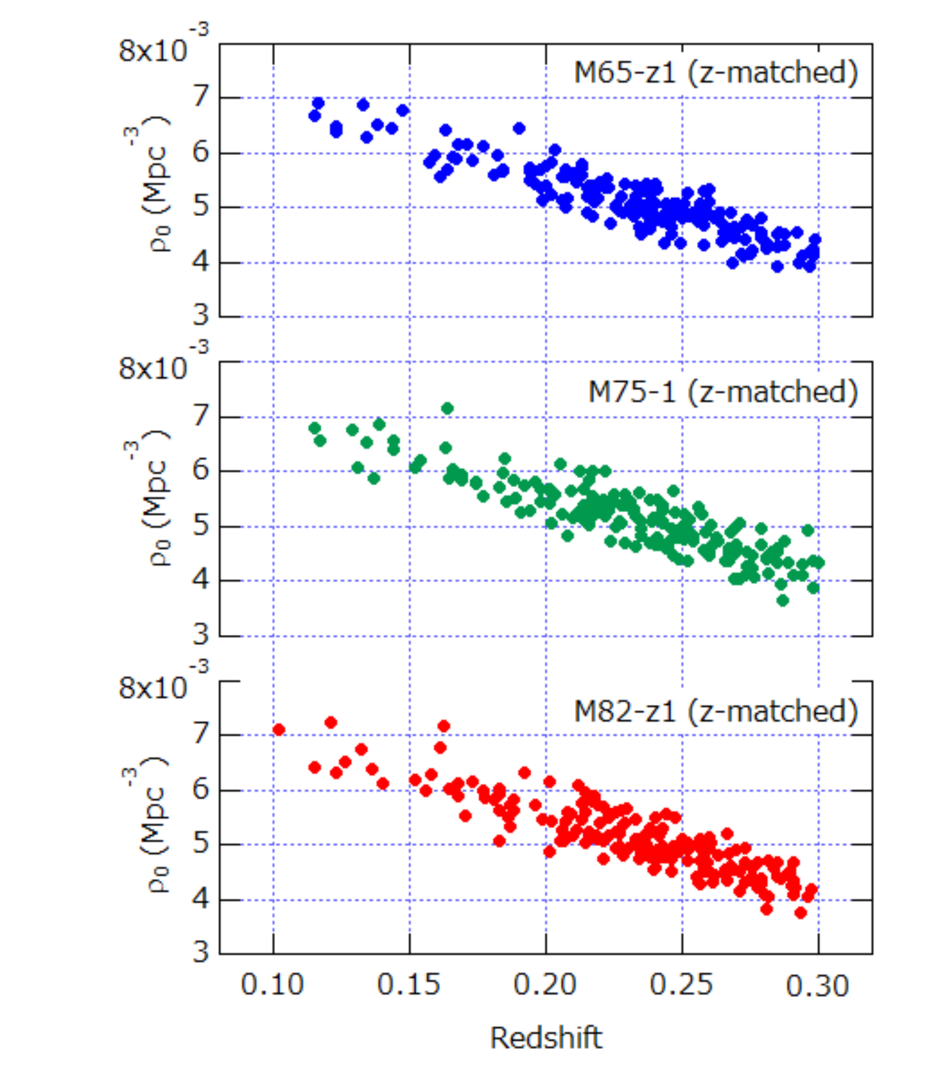
For z1

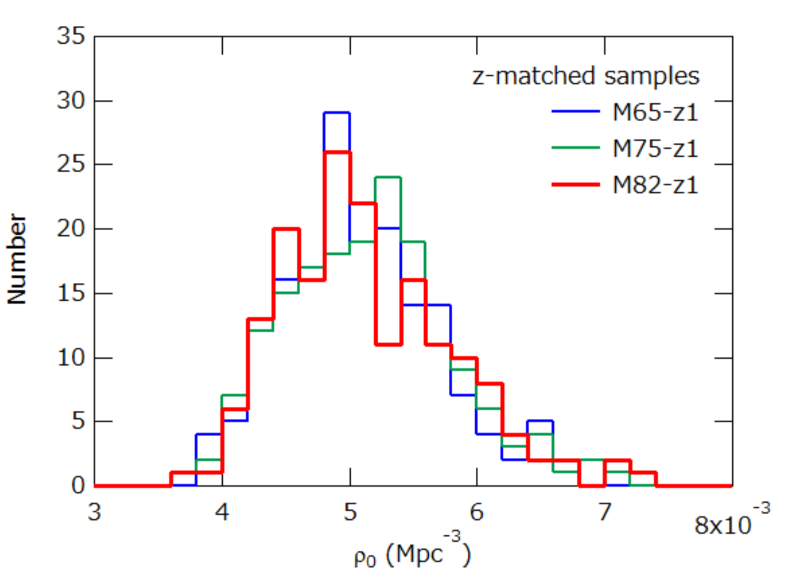
- LFs of M65 & M75 are equivalent.
- In M82 depletion at low luminosity and enhancement at higher luminosity are seen.

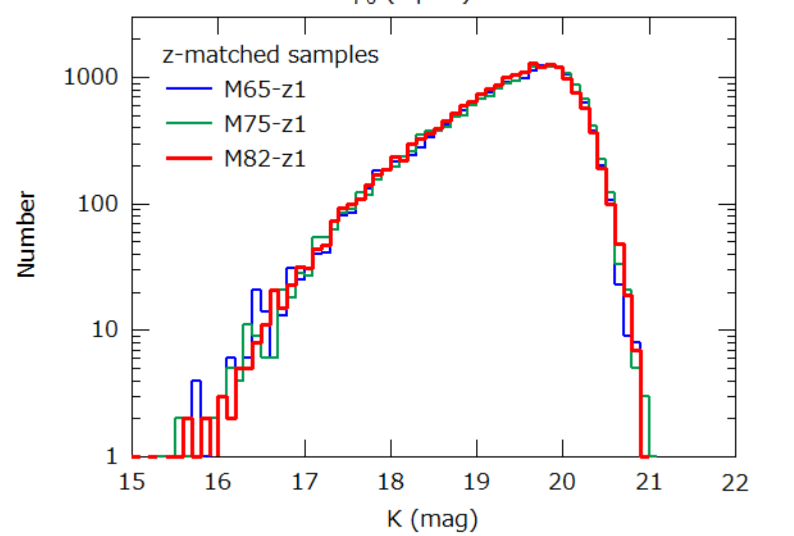
For z2

- Only enhancement of LF is seen. Depletion is not seen due to the detectior limit.

Comparison of the detection limits







No significant difference to make the difference in LFs

Summary

- We found the clustering depends on the M_{BH} especially for $M_{BH} > 10^8 M_\odot$.
    - indication of mass accretion controlled by an external factor
- Increase of red fraction for higher M_{BH} is observed.
    - SMBHs with higher mass reside in a well evolved system, co-evolution with the environment
- Depletion and enhancement of the luminosity function at lower and higher luminosity are observed.
    - fit to the picture of merger scenario.